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Article

Income, Economic Efficiency and Strategic Analysis of Smallholder Buffalo Farming in Biboki Anleu District

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ABSTRACT

Smallholder buffalo farming plays an important role in supporting rural livelihoods in Biboki Anleu District, North Central Timor Regency, particularly as a source of household income, traditional asset, and socio-cultural exchange in local communities. This study aims to analyze farmers' income, economic efficiency, factors affecting income, and strategic development of smallholder buffalo farming. A survey was conducted involving 37 buffalo farmers selected through a census approach. Data were analyzed using income analysis, Return Cost Ratio, multiple linear regression, and SWOT analysis. The results show that buffalo farming generated an average annual income of IDR 108,127,975.60 per farmer, with an R/C ratio of 5.754, indicating that the business is economically feasible and efficient. Feed cost and farming experience significantly influenced farmers' income. The high efficiency was supported by the use of local feed resources and agricultural by-products, such as sago, rice straw, and kabesak leaves, which reduced cash production costs. The study concludes that smallholder buffalo farming has strong economic potential when supported by local resource-based feed management, improved market information, breeding services, and farmer training. Strategic development should prioritize feed processing, institutional support, and population sustainability.

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INTRODUCTION

Indonesia's population increased from 264,161,600 people in 2018 to 275,773,800 people in 2022, with an average population growth rate of 1.08% over the last five years (BPS, 2023). This increasing population growth, along with rising public awareness of food and nutrition, has intensified the demand for food, particularly animal-based protein sources (Sahala et al., 2016; 2023). One of the main sources of animal protein is meat derived from livestock such as cattle, goats, sheep, chickens, and buffaloes (Sahala et al., 2024; Sudirjo et al., 2024).

Smallholder livestock farming plays an important role in Indonesia because it contributes to rural livelihoods, household income, food security, and the availability of animal protein. However, smallholder livestock systems still face several structural problems. These problems include limited access to production inputs, traditional management practices, weak market access, limited capital, and low adoption of technology. These conditions often affect livestock productivity, production costs, and farmers' income. Therefore, improving the economic performance of smallholder livestock farming requires better resource management, especially in rural areas where livestock production depends strongly on local resources and family labor (Goswami et al., 2023).

One of the most important challenges in smallholder livestock farming is feed availability and feed cost. Production efficiency is strongly influenced by how farmers manage available resources, particularly feed inputs, which often represent the largest component of production costs (Alegbeleye et al., 2026). Inefficient feed management can increase production costs and reduce farmers' income. In rural areas, agricultural by-products such as crop residues, rice straw, and other local feed materials provide alternative feed sources that can reduce production costs. However, these resources have not been fully optimized because many farmers still have limited knowledge, technology, and management skills in processing local feed resources. The use of agricultural by-products as livestock feed can improve feed efficiency and reduce production costs in smallholder livestock systems (Martina et al., 2024). In line with this, Liu et al. (2026) explain that agricultural by-products can support more efficient feed use when they are managed properly.

Buffalo farming is one of the local livestock resources that can support meat production and rural economic development in Indonesia. Buffalo are important because they have adaptive capacity under various environmental conditions and can be used for meat production, milk production, and draft power. Buffalo also have socio-cultural value in several regions. Their management systems vary from extensive, semi-intensive, to intensive systems, depending on local resources, farmer capacity, and environmental conditions (Chanda et al., 2025). In intensive systems, buffalo are kept in housing and provided with feed regularly. In semi-intensive systems, buffalo are released for grazing during the day and kept in pens at night. Meanwhile, in extensive or semi-extensive systems, buffalo are mostly raised on grazing land with limited housing management (Momin et al., 2016). These different systems show that buffalo farming is closely related to local ecological and socio-economic conditions (Ozturk et al., 2022).

In smallholder livestock systems, production efficiency is strongly influenced by how farmers manage available resources, particularly feed inputs which represent the largerst component of production costs (Alegbeleye et al., 2026). Inefficient resource utilization often leads to higher production costs and lower income levels. Therefore, improving economic performance through efficient resource management is essential to support the sustainability of livestock farming systems in rural areas (Goswami et al., 2023).

In addition, the availability of agricultural by-products in rural areas, such as crop residues, offers an alternative feed source that has not been fully utilized. These local resources have the potential to reduce feed costs and improve production efficiency, particularly in smallholder livestock systems. However, limited knowledge and management practices among farmers often result in suboptimal utilization of these resources. Recent studies have shown that the use of agricultural by-products as feed can improve feed efficiency and reduce production costs in smallholder livestock systems (Liu et al., 2026; Martina et al., 2024).

At the national level, buffalo development is important because it supports livestock diversification and reduces dependence on more dominant meat sources. In East Nusa Tenggara Province, buffalo farming has a specific role because the province has dryland characteristics, strong local livestock traditions, and high socio-cultural demand for buffalo. The buffalo population in East Nusa Tenggara Province increased by 94,331 heads over the past five years, reaching 172,850 heads in 2022, with an average growth rate of 21.24%. This growth rate was higher than the national average buffalo population growth of 7.49% (BPS, 2023). This condition

indicates that East Nusa Tenggara has strong potential for buffalo development, especially in areas where buffalo are integrated into household livelihoods, traditional practices, and local economic activities.

North Central Timor Regency is one of the main buffalo population centers in East Nusa Tenggara Province. However, the buffalo population in this regency decreased from 841 heads in 2018 to 808 heads in 2022, despite the increasing demand for meat consumption (BPS Kabupaten Timor Tengah Utara, 2022). This decline indicates that the development of buffalo farming still faces serious challenges at the local level. One of the factors contributing to this condition is the high slaughter and sales rate. In Timorese culture, buffalo are traditionally used as bride price, locally known as belis, in marriage proposals. This cultural function increases the demand for buffalo and strengthens their economic value in the community (Sanaky et al., 2022). At the same time, high demand can also create pressure on population sustainability when sales and slaughter are not balanced with proper breeding management.

In East Nusa Tenggara, smallholder buffalo farming also faces environmental and technical constraints. One of the main constraints is the limited availability of feed resources during prolonged dry seasons. Seasonal drought reduces the availability of natural forage and forces farmers to rely on low-quality feed or purchase additional feed at higher costs. This situation can reduce livestock productivity, increase production expenses, and affect farmers' income and economic efficiency. Climate-related stress has been shown to affect livestock systems through feed scarcity, water limitations, and declining animal performance (Rojas-Downing et al., 2017). Similar constraints are relevant in dryland livestock systems, where feed and water availability become critical factors for maintaining production performance (Zungu et al., 2022). Therefore, improving feed management through the utilization of locally available resources is an important strategy to support more efficient buffalo farming systems.

Despite these constraints, smallholder buffalo farming in Biboki Anleu District has considerable potential for development. Farmers use local feed resources such as sago, rice straw, and kabesak leaves to reduce production costs and maintain livestock during periods of feed shortage. These local resources can provide a comparative advantage when they are managed efficiently. However, farmers still face several challenges, including limited market information, low formal education, limited access to livestock technology, weak breeding services, and traditional farm management practices. Socio-economic conditions also influence the performance of smallholder livestock enterprises. Socio-economic factors are related to the position of individuals within a community, including education, economic activities, and income (Powers, 2021). In livestock farming, these factors may include age, land ownership, education level, farming duration, farming experience, household size, and income level (Hadini, 2026).

Income and economic efficiency in smallholder livestock farming are influenced by production costs, livestock production levels, farmer education, herd size, and managerial skills (Phiri et al., 2023). Other factors, such as feed availability and the number of animals raised, also play an important role in determining livestock management decisions (Melesse et al., 2023). In the context of Biboki Anleu District, these factors need to be analyzed because buffalo farming is still managed traditionally and depends heavily on local resources. Understanding how socio-economic and production factors influence income is important for identifying the economic performance of buffalo farming and for formulating appropriate development strategies.

Previous studies have examined livestock income, financial feasibility, and development strategies in different smallholder farming contexts. Sahala et al. (2016) analyzed the financial feasibility of cattle fattening and factors affecting livestock ownership. Sahala et al. (2023) also examined the financial feasibility of Bali cattle fattening in East Nusa Tenggara. Meanwhile, Talakua et al. (2022) applied a SWOT approach to formulate goat farming development strategies, and Bulu et al. (2024) analyzed buffalo farming development strategies in Sumba Timur. These studies provide important insights into livestock business feasibility and strategic development. However, they have not specifically integrated income analysis, economic efficiency, socio-economic determinants, and SWOT-based development strategy in smallholder buffalo farming in Biboki Anleu District. In addition, limited attention has been given to how local feed resources, agricultural by-products, and socio-cultural demand shape the economic performance of buffalo farming in dryland areas.

This study fills this gap by providing an integrated analysis of income, economic efficiency, factors affecting farmers' income, and strategic development of smallholder buffalo farming in Biboki Anleu District, North Central Timor Regency. The novelty of this study lies in its focus on the relationship between local resource utilization, farmer socio-economic characteristics, and the strategic position of buffalo farming in a dryland socio-cultural context. Based on these conditions, this study aims to: (1) analyze the income level of

smallholder buffalo farming; (2) determine the level of economic efficiency; (3) analyze the influence of socio-economic and production factors on farmers' income; and (4) formulate development strategies for smallholder buffalo farming based on internal and external conditions. The findings are expected to support decision-making in livestock development, improve farmers' income, strengthen the utilization of local feed resources, and contribute to community-based agricultural development in East Nusa Tenggara.

RESEARCH METHOD

This study was conducted from June to July 2024 in Biboki Anleu District, North Central Timor Regency. The basic method used in this research was a survey method involving buffalo farmers who raise buffalo under traditional farming systems in Biboki Anleu District, North Central Timor Regency. A quantitative research method was used to calculate farm income, measure economic efficiency using the Return Cost Ratio, and examine the factors affecting farmers' income through multiple linear regression analysis. The strategic analytical approach was applied through SWOT analysis to formulate development strategies for smallholder buffalo farming based on internal and external factors. Therefore, this study did not only describe field conditions but also analyzed the economic performance, determinant factors, and strategic direction of smallholder buffalo farming in Biboki Anleu District.

The research location was determined purposively, with respondents consisting of buffalo farmers in Biboki Anleu District, North Central Timor Regency. This location was selected based on the consideration that it has the highest buffalo population in North Central Timor Regency. In addition, the dominance of traditional farming systems in this area allows for a more comprehensive analysis of smallholder livestock management conditions. Therefore, this location was considered suitable for achieving the objectivesof the study (Tajik et al., 2024)

This study was conducted in Biboki Anleu District, which has a relatively large number of buffalo farmers. All buffalo farmers in the study area were included as respondents using a census approach, resulting in a total of 37 respondents distributed across five villages. The number of respondents in each village was determined based on the number of buffalo farmers who met the inclusion criteria, not based on the total buffalo population. Therefore, villages with larger buffalo populations did not necessarily have a larger number of respondents because buffalo ownership was unevenly distributed among farmers. For example, Ponu Village had the highest buffalo population, but the number of eligible farmers was lower because several farmers owned more buffalo. In contrast, Nifutasi and Kotafoun had lower buffalo populations but a higher number of eligible farmers with smaller herd ownership. Since this study used a census approach, all 37 buffalo farmers who owned at least one buffalo and had been engaged in buffalo farming for at least one year were included as respondents. The distribution of livestock population and number of farmers in the study area is presented in Table 1.

The data analysis methods used in this study included descriptive analysis, income analysis (Syach et al., 2024), business efficiency analysis (Harly et al., 2025; Mayulu et al., 2024), multiple regression analysis using R software (Bulu et al., 2024; Sahala et al., 2016), and SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) (Bulu et al., 2024; Kumar et al., 2025; Talakua et al., 2022).

Table 1
Distribution of Buffalo Population and Farmers

Village	Buffalo Population	Number of Farmers
Ponu	337	10
Nifutasi	56	12
Nonotbatan	2	2
Kotafoun	38	11
Oemanu	12	2
Total	467	37

Source: Processed Primary Data, 2024

Income Analysis

Farm income was calculated using the following formula:

$$\pi = TR - TC \quad (1)$$

where π represents farm income, TR is total revenue obtained from buffalo sales, and TC is the total production cost incurred by farmers.

Efficiency Analysis

Business efficiency was measured using the Return Cost Ratio (R/C), formulated as:

$$\frac{R}{C} = \frac{Total\ Revenue\ (TR)}{Total\ Cost\ (TC)} \quad (2)$$

The decision criteria are as follows: R/C > 1 indicates that the business is feasible, R/C = 1 indicates break-even, and R/C < 1 indicates that the business is not feasible.

Multiple Linear Regression

Multiple linear regression analysis was used to examine the factors affecting farmers' income from smallholder buffalo farming. The dependent variable in this study was farmers' income, while the independent variables consisted of feed cost, capital, farmer age, education level, herd size, farming experience, land size, and labor availability. The regression model is presented as follows:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + e \quad \ldots. \quad (3)$$

Where Y represents farmers' income from buffalo farming, measured in IDR/year; β_0 is the intercept; β_1–β_8 are regression coefficients; X_1 is feed cost, measured in IDR/year; X_2 is capital, measured in IDR/year; X_3 is farmer age, measured in years; X_4 is education level, measured by years of formal education; X_5 is herd size, measured by the number of buffalo owned; X_6 is farming experience, measured in years; X_7 is land size, measured in hectares; X_8 is labor availability, measured by the number of household labor members involved in buffalo farming; and ε is the error term. To support the transparency of the regression procedure, the classical assumption test results are presented in Table 2.

Table 2
Classical Assumption Test Results

No.	Classical Assumption Test	Indicator	Result	Criteria	Conclusion
1	Normality test	Shapiro-Wilk p-value	0.1283	p > 0.05	Residuals are normally distributed
2	Multicollinearity test	VIF	2.1036–9.04777	VIF < 10	No multicollinearity
3	Heteroscedasticity test	Breusch-Pagan p-value	0.8258	p > 0.05	No heteroscedasticity
4	Autocorrelation test	Durbin-Watson p-value	0.5422	p > 0.05	No autocorrelation
5	Linearity test	Ramsey RESET p-value	0.5665	p > 0.05	The model is linear

Source: Processed Primary Data, 2024

SWOT Analysis

SWOT analysis was used to formulate development strategies for smallholder buffalo farming in Biboki Anleu District. This analysis identified internal and external factors that influenced the development of buffalo farming. Internal factors consisted of strengths and weaknesses, while external factors consisted of opportunities and threats. The identification of these factors was based on field observations, structured interviews, questionnaire data, and discussions with key informants, including buffalo farmers, livestock officers, and relevant local stakeholders.

The SWOT analysis was conducted through three stages, namely the input stage, matching stage, and decision stage. In the input stage, internal strategic factors were arranged in the Internal Factor Analysis Summary matrix, while external strategic factors were arranged in the External Factor Analysis Summary matrix. Each factor was assigned a weight ranging from 0.00 to 1.00 based on its level of importance. The total weight of all internal factors and all external factors was equal to 1.00. Each factor was also assigned a rating from 1 to 4. For internal factors, rating 4 indicated a major strength, rating 3 indicated a minor strength, rating 2 indicated a minor weakness, and rating 1 indicated a major weakness. For external factors, rating 4 indicated a major opportunity, rating 3 indicated a minor opportunity, rating 2 indicated a minor threat, and rating 1 indicated a major threat. The weighted score was obtained by multiplying the weight by the rating.

The strategic position was determined by calculating the difference between the total strength score and the total weakness score as the X-axis, and the difference between the total opportunity score and the total threat score as the Y-axis. The result was then plotted into a SWOT quadrant diagram to determine the strategic position of smallholder buffalo farming. In the matching stage, strategic alternatives were formulated using a SWOT matrix consisting of SO, WO, ST, and WT strategies. SO strategies were formulated by using strengths to take advantage of opportunities. WO strategies were formulated by using opportunities to overcome weaknesses. ST strategies were formulated by using strengths to minimize threats. WT strategies were formulated by minimizing weaknesses and avoiding threats. In the decision stage, the priority strategy was determined based on the SWOT quadrant position and the relevance of each strategy to income, economic efficiency, management practices, and field conditions of smallholder buffalo farming in Biboki Anleu District.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Farmers

Respondent characteristics describe the general condition of buffalo farmers involved in this study, including age, education level, main occupation, farming experience, household size, herd size, land ownership, and participation in training or extension programs. These characteristics provide important contextual information to understand the socio-economic conditions that may influence farm performance. The distribution of these characteristics is presented in Table 3.

The socio-economic characteristics of farmers reveal several important patterns relevant to farm performance. Most farmers are within the productive age group (51.35%), indicating sufficient labor availability for livestock management activities. Farmers in productive age groups generally have better physical capacity and contribute more effectively to livestock productivity, as resported by Dill et al. (2015), Indrawirawan et al. (2022), Kusumastuti et al. (2023) and Sahala et al. (2016 and 2024) stated that productive-age farmers generally possess better physical endurance in managing buffalo grazing activities. However, the education level remains relatively low, with 64.87% of farmers having only completed elementary school, which may limit their ability to adopt improved livestock management practices, particularly in feed utilization and marketing (Indrawirawan et al., 2022).

The majority of respondents (94.60%) reported farming as their main occupation, indicating that buffalo farming is generally treated as a secondary activity. This condition may reduce the level of attention given to livestock management, particularly in terms of feeding and animal care practices, as suggested in previous studies (Andaruisworo, 2022; Sahala et al., 2016; 2023). In terms of farming experience, most farmers have more than 10 years of experience, with 45.94% having 11–20 years of experience, indicating substantial practical knowledge. This finding is consistent with the regression results, which show that farming experience significantly influences farmers' income (Ibrahim et al., 2020; Purnomo et al., 2021).

Household characteristics also play an important role in farm operations. Most farmers have 4–5 family dependents (48.65%), which may contribute to the availability of family labor and reduce the need for hired labor. Despite this, most farmers operate on a small scale, with 56.76% owning only 1–5 buffalo, reflecting the characteristics of smallholder farming systems. Land ownership is also relatively limited, with 51.35% owning less than or equal to 0.25 ha, but this land still supports the availability of agricultural residues and crop by-products used as livestock feed (Fitriani et al., 2023; Heryadi & Fitrianti, 2022).

A notable finding is that none of the farmers have participated in training or extension programs related to buffalo farming. This lack of institutional support limits farmers' access to innovation and improved management practices, particularly in addressing feed shortages during the dry season. As a result, farmers rely heavily on locally available resources such as sago and agricultural waste to sustain production. Previous studies emphasize that extension services play an important role in improving farmers' decision-making and facilitating the adoption of new technologies in livestock farming (Lamarang et al., 2017).

Table 3
Characteristics of Buffalo Farmers in Biboki Anleu District

No	Farmer Characteristics	Number (Persons)	Percentage (%)
1	Age		
	17–55 years	19	51.35
	>55 years	18	48.65
2	Education Level		
	No formal education	6	16.21
	Elementary school	24	64.87
	Junior high school	1	2.70
	Senior high school	4	10.81
	Diploma/Bachelor	2	5.41
3	Main Occupation		
	Farmer	35	94.60
	Civil servant	1	2.70
	Retired	1	2.70
4	Farming Experience (years)		
	1–10	2	5.41
	11–20	17	45.94
	21–30	6	16.22
	>30	12	32.43
5	Family Dependents		
	0–3 persons	14	37.84
	4–5 persons	18	48.65
	>5 persons	5	13.51
6	Number of Buffalo Owned		
	1–5 head	21	56.76
	6–10 head	11	29.73
	>10 head	5	13.51
7	Land Ownership		
	≤0.25 ha	19	51.35
	0.251–0.50 ha	9	24.33
	>0.50 ha	9	24.33
8	Training/Extension Experience		
	Yes	0	0
	No	37	100

Source: Processed Primary Data, 2024

Management Practices and Local Resource Utilization

Buffalo farming management in Biboki Anleu District reflects the characteristics of traditional smallholder livestock systems. Farmers generally combine grazing activities with simple household-based management. Buffalo are released to pasture areas, forest edges, and surrounding open land for grazing, while farmers provide additional feed and water at certain times. This pattern indicates that buffalo farming in the study area is closer to a semi-intensive system because farmers still provide some control over feeding, watering, and monitoring, although housing, breeding, and health management remain limited. This condition is consistent with Momin et al. (2016), who explain that semi-intensive buffalo farming combines grazing activities with farmer intervention in feeding and housing. However, compared with more structured buffalo farming systems described by Ozturk et al. (2022), management practices in Biboki Anleu are still less standardized because farmers rely heavily on natural grazing, simple equipment, and traditional knowledge.

Feed management is one of the most important aspects of buffalo farming in the study area. Farmers use green forage, rice straw, sago, Gliricidia leaves, and kabesak leaves as the main feed resources. During the rainy season, forage availability is relatively sufficient because grazing land and surrounding vegetation can support livestock needs. During the dry season, forage availability declines, and farmers rely more heavily on sago and agricultural residues. This condition shows that local resource utilization is not only a field practice but also an adaptive strategy to maintain buffalo production during seasonal feed shortages. Conceptually, this practice supports the principle of resource efficiency in smallholder farming because farmers use locally available inputs to reduce dependence on purchased feed. This finding is in line with Martina et al. (2024), who state that agricultural by-products can function as fibrous feed resources for livestock when they are properly utilized.

The use of local feed resources has a direct relationship with economic efficiency. In livestock farming, feed often represents the largest component of production costs. Therefore, farmers' ability to use sago, rice straw, Gliricidia leaves, and kabesak leaves can reduce cash expenditure and support higher income. This finding is consistent with the cost structure analysis in this study, where feed cost was the dominant production cost but was partly controlled through the use of local resources. Alegbeleye et al. (2026) also emphasize that feed inputs strongly influence livestock production efficiency. Therefore, the use of agricultural waste and local feed resources in Biboki Anleu can be interpreted as a comparative advantage of smallholder buffalo farming, especially in dryland areas with limited access to commercial feed.

Despite these advantages, feed management in the study area still has several limitations. Farmers generally provide feed in fresh or simple forms and have not widely applied feed processing technologies such as silage or fermentation. This condition differs from the concept of improved feed management, which emphasizes feed preservation, nutrient improvement, and year-round feed availability. Liu et al. (2026) explain that agricultural by-products can improve feed-use efficiency when supported by proper processing and management. Therefore, the limited use of feed processing technology in Biboki Anleu indicates that local resources have not yet been fully optimized. This gap is important because dry-season feed scarcity remains one of the main threats to buffalo productivity and economic efficiency.

Breeding management also remains traditional. Farmers rely almost entirely on natural mating, while artificial insemination has not been implemented due to limited services, lack of trained inseminators, and limited availability of buffalo semen. This condition may increase the risk of inbreeding and reduce opportunities for genetic improvement. Conceptually, reproductive management is an important element of livestock productivity because it affects herd growth, animal quality, and long-term business sustainability. The absence of structured breeding services shows that buffalo farming development in the study area still requires institutional support from livestock service agencies, especially in reproductive technology, artificial insemination services, and farmer training.

Housing and animal health management are also relatively simple. Some farmers tether buffalo under trees or in fenced areas, while others allow buffalo to roam freely during the dry season. Simple housing reduces cash costs, but it may limit animal protection, disease control, and manure management. Farmers reported common health problems such as bloating and diarrhea, while buffalo mortality was mainly associated with feed shortages during the dry season. This condition shows that the low-cost management system supports short-term efficiency, but it also creates risks for long-term productivity. Therefore, improved housing, disease prevention, manure management, and feed preservation are needed to balance cost efficiency and production sustainability.

Farmers also use basic equipment such as machetes, axes, hoes, sickles, brooms, boots, crowbars, and ropes to support daily livestock activities. These tools help farmers collect feed, clean livestock areas, prepare simple housing, and handle buffalo. However, the available equipment remains basic and does not yet support more advanced management practices, such as feed processing, manure processing, or improved housing systems. This condition indicates that smallholder buffalo farming in the study area still operates with low external input and limited technology. From an efficiency perspective, this system can reduce production costs. However, from a development perspective, limited technology can restrict productivity improvement.

Marketing practices show that buffalo are mainly sold as live animals through direct transactions with traders. Transactions are usually witnessed by village authorities and supported by official sales certificates. Buffalo prices vary across villages depending on animal condition, estimated body weight, and farmers' bargaining position. The highest buffalo price was found in Ponu Village at approximately IDR 35,000,000 per animal, while the lowest price was found in Nifutasi Village at approximately IDR 7,500,000 per animal. This price difference indicates unequal access to market information and weak price standardization. From a strategic perspective, limited market information can reduce farmers' bargaining power and affect income. Therefore, improving price information systems, farmer groups, and collective marketing is important to strengthen the economic position of smallholder buffalo farmers.

Overall, buffalo farming management and local resource utilization in Biboki Anleu District show both strengths and limitations. The main strength lies in farmers' ability to use local feed resources and agricultural residues to reduce production costs. This practice supports the high economic efficiency found in this study. However, management practices remain traditional, especially in feed processing, breeding, housing, health control, equipment use, and marketing. Therefore, this section supports the study objectives by explaining why local resource utilization contributes to income and efficiency, while also providing a basis for formulating development strategies through SWOT analysis.

Cost Structure and Farm Income

The cost and revenue calculations in this study are based on the total number of buffalo (213 head) owned by 37 farmers, and are also presented in average terms per respondent. The cost structure of buffalo farming in the study area consists of variable costs and fixed costs, with total production costs reaching IDR 843,457,105 per year, or an average of IDR 23,048,700.13 per farmer per year. This relatively moderate level of production cost, when compared to the total revenue generated, indicates that buffalo farming has strong potential to generate economic returns. The structure of these costs reflects the characteristics of smallholder farming systems, which rely heavily on locally available resources and family labor inputs.

Variable costs dominate the total production costs, particularly feed and labor expenses. Feed costs represent the largest component, amounting to IDR 500,356,775 per year or approximately 59.32% of total production costs. This finding highlights that feed is the most critical factor influencing the cost structure of buffalo farming. The types of feed used include rice straw, sago, Gliricidia leaves, and Kabesak leaves, which are commonly available in the surrounding environment. The dominance of feed costs is consistent with the general characteristics of livestock farming systems, where feed typically accounts for the largest share of total production costs.

A substantial portion of these feed resources, particularly Gliricidia and Kabesak leaves, are obtained from locally available sources and are categorized as non-cash inputs. This condition provides a significant economic advantage for farmers, as it reduces their dependence on purchased feed inputs. During the dry season, when natural forage becomes scarce, farmers increasingly rely on alternative feed sources such as sago and agricultural residues. This adaptive strategy enables farmers to maintain livestock productivity while minimizing additional expenses. Therefore, the utilization of local resources plays a crucial role in stabilizing production costs and supporting the sustainability of buffalo farming systems in the study area.

Labor costs constitute the second largest component, amounting to IDR 237,179,330 per year. This reflects the labor-intensive nature of buffalo farming, particularly under semi-intensive and extensive management systems where farmers are directly involved in daily activities such as grazing, feeding, and monitoring livestock. In many cases, labor is supplied by family members, which helps reduce cash expenditures. Other cost components, including animal health, housing maintenance, water, electricity, and transportation, contribute relatively small proportions to total production costs. Overall, this cost structure indicates that feed and labor are the primary determinants of total production costs in buffalo farming.

Table 4
Cost, Revenue, Income, and Efficiency of Buffalo Agribusiness (213 head; n = 37)

Income Components	Total Amount (IDR/year)	Average Amount (IDR/respondent/year)
(I) Farm Revenue		
Livestock Sales	4,853,500,000	131,176,675.70
Total Revenue	4,853,500,000	131,176,675.70
(II) Variable Costs		
Feed Costs	500,356,775	15,523,156.08
Health Costs	2,047,000	55,324.33
Labor	237,179,330	6,410,252.16
Housing Maintenance	1,980,000	53,513.51
Water and Electricity	14,100,000	381,081.08
Transportation	6,975,000	188,513.51
Total Variable Costs	762,638,105	22,611,840.67
(III) Fixed Costs		
Housing Depreciation	70,500,000	381,081.08
Equipment Depreciation	10,319,000	55,778.38
Total Fixed Costs	80,819,000	436,859.46
Total Costs (II+III)	843,457,105	23,048,700.13
IV. Farm Income {I – (II + III)}	4,010,042,895	108,127,975.60
R/C Ratio	5.754	-

Source: Processed Primary Data, 2024

The total revenue generated from buffalo farming reached IDR 4,853,500,000 per year, with an average of IDR 131,176,675.70 per farmer per year. Revenue is primarily derived from the sale of live buffalo, indicating that the farming system remains relatively simple and has not yet been diversified into value-added products such as processed meat or manure-based inputs. This reliance on a single source of revenue suggests that there is still considerable potential to improve income through diversification strategies and better market access. In addition, variations in revenue among farmers are influenced by differences in herd size, animal condition, and market price at the time of sale.

Based on the difference between total revenue and total production costs, the total income obtained from buffalo farming reached IDR 4,010,042,895 per year, with an average income of IDR 108,127,975.60 per farmer per year. This level of income indicates that buffalo farming provides substantial economic benefits for farmers and contributes significantly to household livelihoods. The relatively high income achieved by farmers is closely related to their ability to control production costs, particularly through the efficient use of locally available feed resources.

As presented in Table 4, the cost structure shows that feed cost was the largest production cost component, accounting for IDR 500,356,775 per year or 59.32% of total production costs. This result is consistent with the previous discussion on local resource utilization, where farmers used sago, rice straw, Gliricidia leaves, and kabesak leaves to reduce dependence on commercial feed. Therefore, the relationship between cost structure and income becomes clearer because the use of local feed resources helped control production costs and contributed to the average annual income of IDR 108,127,975.60 per farmer. This finding also supports the economic efficiency result, where buffalo farming achieved an R/C ratio of 5.754, indicating that resource efficiency plays an important role in improving the economic performance of smallholder buffalo farming.

Economic Efficiency of Buffalo Farming

The economic efficiency of buffalo farming in the study area was evaluated using the Return Cost Ratio (R/C), which compares total revenue with total production costs. This indicator is commonly used to assess whether livestock farming is financially feasible and economically efficient. A farming business is considered feasible when the R/C ratio is greater than 1 because revenue exceeds total production costs (Harly et al., 2025). Based on the data presented in Table 2, the R/C ratio of buffalo farming in Biboki Anleu District was 5.754. This

means that every IDR 1 spent on production generated IDR 5.754 in revenue. Therefore, smallholder buffalo farming in the study area can be categorized as economically feasible and profitable.

The high R/C ratio in this study was influenced not only by cost efficiency but also by strong demand for buffalo. Buffalo have significant economic and socio-cultural value in the study area, particularly for traditional ceremonies such as belis payments and conflict resolution. This cultural function contributes to stable demand and relatively high market prices. Sanaky et al. (2022) found that buffalo have important social and cultural value in community life in eastern Indonesia. In addition, demand from outside the region further increases market opportunities, enabling farmers to sell buffalo at favorable prices. This condition shows that economic efficiency in buffalo farming is supported by both production efficiency and demand-side factors.

From the cost perspective, feed represented the largest component of production costs, amounting to IDR 500,356,775 or 59.32% of total production costs, as shown in Table 2. This indicates that feed cost is the most influential factor in determining economic efficiency. The ability to control feed costs therefore becomes a key determinant of farm profitability. Alegbeleye et al. (2026) explain that feed inputs are one of the most important factors affecting livestock production costs and efficiency. This finding is also consistent with Mayulu et al. (2024), who emphasize that livestock business feasibility depends on the balance between revenue and production costs.

One of the main factors contributing to cost efficiency was the utilization of local resources and agricultural waste as alternative feed sources. Farmers relied on locally available materials such as sago, rice straw, Gliricidia leaves, and kabesak leaves, which were generally low-cost or categorized as non-cash inputs. This practice provided an economic advantage because it reduced dependence on commercial feed and lowered overall production costs. Martina et al. (2024) state that agricultural by-products can be used as fibrous feed resources for livestock when they are properly managed. Similarly Liu et al. (2026) explain that agricultural by-products can improve feed-use efficiency when supported by appropriate processing and utilization.

The use of local feed resources becomes particularly important during the dry season, when natural forage availability declines. Under these conditions, farmers adopt adaptive strategies by using agricultural residues and other locally available feed materials to maintain livestock performance. This ability to substitute expensive inputs with readily available resources represents a comparative advantage in smallholder buffalo farming systems. Rojas-Downing et al. (2017) explain that seasonal and climate-related stress can affect livestock systems through feed scarcity, water limitations, and declining animal performance. Therefore, the utilization of local feed resources in Biboki Anleu District can be understood as an adaptation strategy to reduce production risks during periods of feed shortage.

As a result, the high R/C ratio observed in this study was not only driven by revenue generation but also by effective cost management, especially in feed utilization. The integration of local resources and agricultural waste into the feeding system directly contributed to reducing production costs, which then improved economic efficiency. This finding supports Goswami et al. (2023), who state that resource interaction in smallholder farming systems is closely related to farm sustainability. Therefore, the strategic use of local resources is a key factor in improving the economic performance and sustainability of smallholder buffalo farming in dryland areas.

Factors Affecting Farmer's Income

Before interpreting the multiple linear regression results, the model was first evaluated through classical assumption tests. As shown in Table 3, the regression model met the basic requirements of ordinary least squares estimation. The residuals were normally distributed, no serious multicollinearity was detected, the model was free from heteroscedasticity, and the Durbin-Watson value indicated no serious autocorrelation. Therefore, the regression model was considered appropriate for further analysis and fulfilled the requirements for producing Best Linear Unbiased Estimator estimates.

Based on Table 4, the results of the multiple linear regression analysis show that the model has strong explanatory power. The coefficient of determination value was **0.8059**, indicating that **80.59%** of the variation in farmers' income from smallholder buffalo farming could be explained by feed cost, capital, farmer age, education level, herd size, farming experience, land size, and labor availability. The remaining **19.41%** was influenced by other factors outside the model, such as market price, animal health, access to extension services, feeding quality, and farm management practices.

The adjusted coefficient of determination value was **0.7504**, indicating that the model remained stable after adjustment for the number of independent variables. The simultaneous test produced an **F-value of 14.53** with a significance level of **0.000**. This result indicates that all independent variables jointly had a significant effect on farmers' income from smallholder buffalo farming at the 1% significance level. The final empirical regression model based on the R Studio output is written as follows:

$$\mathbf{Y = -1{,}630{,}000 + 7{,}030{,}000X_1 + 4{,}469{,}000X_2 + 8{,}169{,}000X_3 + 2{,}898{,}000X_4 + 1{,}597{,}000X_5 + 1{,}609{,}000X_6 + 1{,}870{,}000X_7 + 3{,}570{,}000X_8 + \varepsilon}$$

Where Y represents farmers' income from buffalo farming; X_1 represents feed cost; X_2 represents capital; X_3 represents farmer age; X_4 represents education level; X_5 represents herd size; X_6 represents farming experience; X_7 represents land size; X_8 represents labor availability; and ε represents the error term.

The partial t-test results show that feed cost (X_1) had a positive and highly significant effect on farmers' income, with a regression coefficient of IDR 7,030,000 and a significance value of 0.000. This indicates that feed cost was the strongest factor associated with farmers' income in the model. The positive coefficient suggests that higher feed expenditure was associated with higher farmers' income, which may reflect better feeding quality, improved animal productivity, and more intensive buffalo management. This finding is consistent with studies on livestock farming which show that feed-related production costs can significantly influence farm income when they support productivity and output quality. Haruna et al. (2025)) found that feed cost and breeder experience significantly affected layer chicken farm income, while Haloho et al. (2013) found that forage cost and concentrate feed cost significantly affected dairy cattle farmers' profit.

Farming experience (X_6) also had a positive and significant effect on farmers' income, with a regression coefficient of **IDR 1,609,000** and a significance value of **0.0416**. This result indicates that more experienced buffalo farmers tended to generate higher income. Farming experience may improve farmers' ability to manage feed, recognize animal health problems, use local resources, reduce unnecessary costs, and make better production decisions. This finding is in line with livestock income research showing that farmer or breeder experience is an important factor in improving farm management and income performance. Haruna et al. (2025) also reported that breeder experience had a positive effect on farm income because experienced farmers are generally more capable of managing production risks and preventing income loss.

Meanwhile, **capital (X_2), farmer age (X_3), education level (X_4), herd size (X_5), land size (X_7), and labor availability (X_8)** did not show statistically significant effects on farmers' income because their significance values were greater than 0.05. This finding indicates that these variables did not play a dominant role in explaining income differences among buffalo farmers in the study area. The non-significant effect may be caused by the relatively homogeneous characteristics of respondents, especially in terms of herd ownership, land size, household labor patterns, and production scale. In smallholder buffalo farming, farmers often manage livestock using similar traditional practices, so differences in these variables may not create strong variation in income.

The non-significant effect of capital differs from the findings of Haloho et al. (2013), who found that capital significantly affected dairy cattle farmers' profit. This difference may be caused by differences in livestock type, production orientation, farm scale, and capital utilization. Dairy cattle farming usually requires more intensive capital allocation for feed, housing, milking equipment, and health management. In contrast, smallholder buffalo farming often relies more heavily on local resources, family labor, traditional feeding systems, and non-intensive management. Therefore, capital may not automatically increase income unless it is used directly for productivity-enhancing activities.

The non-significant effects of farmer age and education level also indicate that formal demographic characteristics were not the main drivers of income in this model. Older age does not always reflect better farm performance if it is not accompanied by adaptive management practices. Similarly, formal education may not directly increase income when buffalo farming knowledge is mainly obtained through practical experience, family tradition, and local knowledge. This explains why farming experience had a stronger effect than education level in the model.

Overall, the results indicate that farmers' income from smallholder buffalo farming was mainly influenced by feed cost and farming experience. These findings show that income improvement should focus on better feed management and strengthening farmers' practical capacity. The results also suggest that

increasing capital, land ownership, herd size, or labor availability may not be sufficient if these factors are not accompanied by effective management, productive feed use, and accumulated farming experience.

Development Strategy Based on SWOT Analysis

The development strategy for smallholder buffalo farming in Biboki Anleu District was formulated using SWOT analysis. The identification of internal and external factors was based on the results of income analysis, economic efficiency analysis, regression analysis, field observations, and interviews with farmers and relevant stakeholders. The internal factors consisted of strengths and weaknesses, while the external factors consisted of opportunities and threats. This analysis was important because buffalo farming in the study area showed high economic efficiency, but still faced several constraints related to feed availability, market information, breeding services, and livestock population sustainability. The internal factor analysis is presented in Table 6.

The results in Table 6 show that the total strength score was 1.89, while the total weakness score was 0.65. The difference between the strength and weakness scores was 1.24. This result indicates that the internal condition of smallholder buffalo farming in Biboki Anleu District is relatively strong. The main strength is the availability of local feed resources, including sago, rice straw, and kabesak leaves. These resources support cost efficiency because they reduce farmers' dependence on commercial feed. This finding is consistent with the cost structure analysis, where feed represented the largest component of production costs. The use of agricultural by-products as livestock feed can also support feed efficiency and reduce production costs in smallholder livestock systems (Liu et al., 2026; Martina et al., 2024).

The socio-cultural value of buffalo was also identified as a major strength. Buffalo are used in belis payments, conflict resolution, and other traditional practices. This function creates stable demand and strengthens the economic value of buffalo in local communities. This finding is in line with Sanaky et al.(2022), who reported that buffalo have important value in the social order of communities in eastern Indonesia. In addition, the productive age of farmers supports labor availability for livestock management activities, especially grazing, feeding, and animal monitoring.

The main weaknesses were limited access to market price information, low formal education, and limited marketing skills. These factors are classified as weaknesses because they reduce farmers' bargaining position and limit their ability to adopt improved livestock management practices. Low education may also affect farmers' ability to process feed, manage reproduction, and access market information. This condition is relevant to Powers (2021), who explains that socio-economic status is closely related to education, economic activities, and income. It is also consistent with Hadini (2026), who states that education, farming experience, land ownership, and income are important socio-economic factors in livestock farming.

Table 5
Results of Regression Analysis Using R Software

Variable	B (Regression Coefficient)	t-value	Significance
Constant	-1,630,000	-1.734	0.093ns
Feed Cost	7,030,000	5.23	0.000***
Capital	4,469,000	0.829	0.4143ns
Farmer Age	8,169,000	1.054	0.3007ns
Education Level	2,898,000	0.098	0.9227ns
Herd Size	1,597,000	0.882	0.3855ns
Farming Experience	1,609,000	2.136	0.0416*
Land Size	1,870,000	1.487	0.1483ns
Labor Availability	3,570,000	0.807	0.4263ns

Source: Processed Primary Data, 2024

Note : *p< 0.05;**p, 0.01; ***p , 0.001; ns= not significant

Table 6
Internal Factor Analysis Summary of Smallholder Buffalo Farming

No	Internal Factors	Weight	Rating	Weighted Score
Strengths				
S1	Availability of local feed resources such as sago, rice straw, and kabesak leaves	0.22	4	0.88
S2	Buffalo have high socio-cultural value in belis payments and conflict resolution	0.17	4	0.68
S3	Most farmers are within the productive age category	0.11	3	0.33
	Total Strength Score	0.50		1.89
Weaknesses				
W1	Farmers have limited access to up-to-date buffalo price information	0.18	1	0.18
W2	Farmers' formal education level is relatively low	0.17	1	0.17
W3	Farmers have limited skills in the livestock selling process	0.15	2	0.30
	Total Weakness Score	0.50		0.65
	Total Internal Score	1.00		2.54

Source: Processed Primary Data, 2024

Table 7
External Factor Analysis Summary of Smallholder Buffalo Farming

No	External Factors	Weight	Rating	Weighted Score
Opportunities				
O1	Demand for buffalo comes from outside East Nusa Tenggara	0.16	4	0.64
O2	Availability of extensive grazing land	0.12	3	0.36
O3	Buffalo prices are relatively high	0.17	4	0.68
O4	Government policies support superior local buffalo breeds	0.10	3	0.30
	Total Opportunity Score	0.55		1.98
Threats				
T1	High number of buffalo sales without limitation	0.14	2	0.28
T2	Absence of artificial insemination and high risk of inbreeding	0.12	1	0.12
T3	Competition from other buffalo-producing regions	0.08	2	0.16
T4	Difficulty in obtaining green forage during the dry season	0.15	1	0.15
T5	High slaughter rate of buffalo for consumption	0.06	2	0.12
	Total Threat Score	0.45		0.83
	Total External Score	1.00		2.81

Source: Processed Primary Data, 2024

The results in Table 7 show that the total opportunity score was 1.98, while the total threat score was 0.83. The difference between the opportunity and threat scores was 1.15. This result indicates that smallholder buffalo farming in Biboki Anleu District has strong external opportunities. The main opportunities are high buffalo prices and demand from outside East Nusa Tenggara. These conditions can improve farmers' income if supported by better market information, collective marketing, and institutional support. The availability of extensive grazing land also supports low-cost production systems because farmers can use local natural resources for grazing.

However, several external threats need to be considered. The high number of buffalo sales without limitation can reduce population sustainability. The absence of artificial insemination services can increase the risk of inbreeding and limit genetic improvement. Feed scarcity during the dry season is also a major threat because it can reduce livestock productivity and increase production costs. Climate-related stress can affect

livestock systems through feed scarcity, water limitation, and declining animal performance (Rojas-Downing et al., 2017). Therefore, feed preservation, breeding management, and sales regulation are needed to maintain the long-term sustainability of buffalo farming.

The SWOT coordinate was calculated by subtracting the total weakness score from the total strength score and subtracting the total threat score from the total opportunity score. The calculation is presented as follows:

$X = S - W = 1.89 - 0.65 = 1.24$
$Y = O - T = 1.98 - 0.83 = 1.15$

Where **X** represents the internal strategic position, **S** represents the total strength score, **W** represents the total weakness score, **Y** represents the external strategic position, **O** represents the total opportunity score, and **T** represents the total threat score.

Based on these calculations, the SWOT coordinate is (1.24; 1.15). This position is located in Quadrant I, which indicates an aggressive strategy. This means that smallholder buffalo farming in Biboki Anleu District has strong internal strengths and favorable external opportunities. Therefore, the development strategy should focus on using existing strengths to capture available opportunities.

The position in Quadrant I indicates that buffalo farming development should prioritize aggressive strategies. These strategies include strengthening local feed resource utilization, improving market access, developing breeding services, and strengthening institutional support. This position is consistent with the economic analysis, which shows that buffalo farming is economically feasible with an R/C ratio of 5.754. The result also supports the regression analysis, where feed cost and farming experience significantly influenced farmers' income. Therefore, development strategies should focus on strengthening feed efficiency, farmer capacity, and market institutions. The SWOT matrix is presented in Table 8.

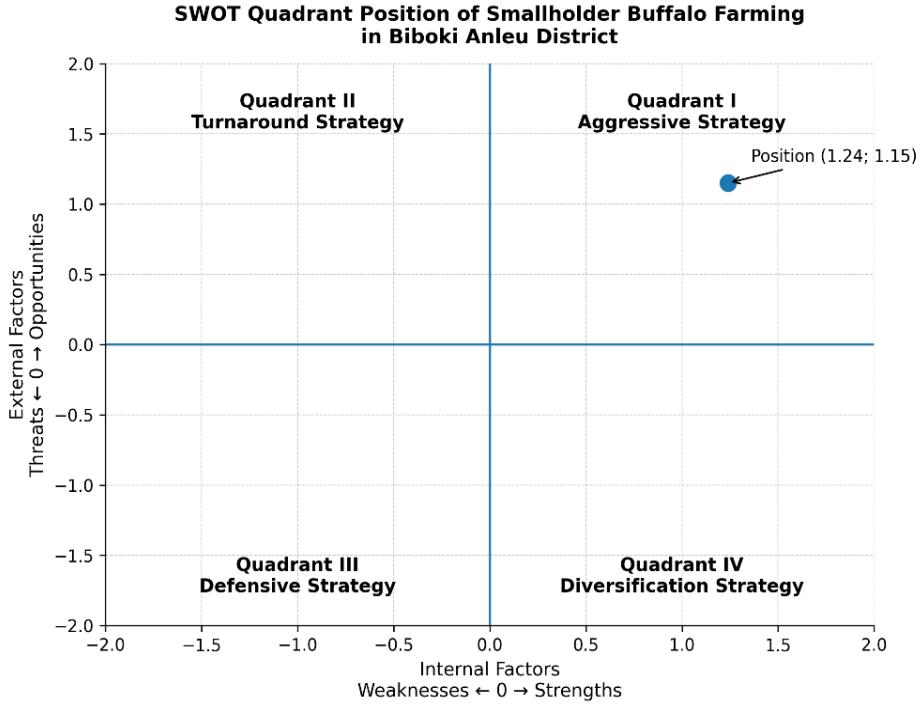


Figure 1
SWOT Quadrant of Smallholder Buffalo Farming in Biboki Anleu District
Source: Processed Primary Data, 2024

Table 8
SWOT Matrix of Smallholder Buffalo Farming in Biboki Anleu District

Internal and External Factors	Strengths	Weaknesses
Opportunities	SO Strategies. S1-O1-O3: Strengthen the utilization of local feed resources such as sago, rice straw, and kabesak leaves to support efficient production and capture high market demand from outside East Nusa Tenggara. S2-O3: Optimize the socio-cultural value of buffalo to maintain stable demand and improve farmers' income through better marketing systems. S3-O4: Strengthen the role of productive-age farmers through technical assistance, breeding services, and institutional programs supported by local government.	WO Strategies W1-O1-O3: Improve farmers' access to current buffalo price information so that they can respond to high market demand and obtain better selling prices. W2-O4: Provide training and extension programs on livestock management, feed processing, and business planning by utilizing government support for local buffalo development. W3-O1-O3: Improve farmers' marketing and negotiation skills to increase bargaining power in livestock sales.
Threats	ST Strategies S1-T4: Develop silage and feed processing from local agricultural by-products to reduce feed shortages during the dry season. S2-T1-T5: Strengthen local regulations on buffalo sales and slaughter, especially productive female buffalo, to maintain population sustainability. S3-T2: Improve breeding management by involving productive-age farmers in artificial insemination programs and reproductive management training.	WT Strategies W2-T2-T4: Conduct regular training on feed preservation, reproductive management, and disease prevention to reduce production risks. W1-W3-T3: Strengthen farmer groups and collective marketing systems to reduce competition pressure from other regions. W2-W3-T1-T5: Increase farmer awareness of sustainable buffalo population management through extension and village-level livestock monitoring.

Source: Processed Primary Data, 2024

Based on the SWOT matrix, the main development strategy recommended for smallholder buffalo farming in Biboki Anleu District is the SO strategy. This strategy is appropriate because the SWOT position is located in Quadrant I. The SO strategy emphasizes the use of internal strengths to take advantage of external opportunities. The priority strategy is to strengthen the utilization of local feed resources and agricultural by-products to support low-cost production while responding to high market demand and favorable buffalo prices.

The use of local feed resources such as sago, rice straw, and kabesak leaves should be strengthened through feed processing technology, especially silage production. This strategy is important because feed cost represents the largest component of production costs and directly affects farm income and economic efficiency. Market access also needs to be improved through better price information, farmer group strengthening, and institutional support. In addition, breeding services, including artificial insemination and reproductive management, are needed to maintain buffalo population sustainability and improve genetic quality. Therefore, the strategic development of buffalo farming should integrate feed efficiency, market strengthening, breeding improvement, and farmer capacity building.

CONCLUSION

This study concludes that smallholder buffalo farming in Biboki Anleu District is economically feasible and efficient. The average income obtained by farmers reached IDR 108,127,975.60 per farmer per year, while the R/C ratio was 5.754. This result indicates that every production cost incurred by farmers generated higher revenue and that buffalo farming provides an important contribution to rural household income. The high economic efficiency was mainly supported by the utilization of local feed resources and agricultural by-products, such as sago, rice straw, and kabesak leaves, which reduced cash production costs. The regression results also showed that feed cost and farming experience significantly influenced farmers' income, while capital, farmer age, education level, herd size, land size, and labor availability did not show significant effects. The SWOT analysis placed smallholder buffalo farming in Quadrant I, indicating an aggressive development strategy. Therefore, the development of buffalo farming should focus on strengthening the use of local feed resources, improving feed processing technology such as silage, expanding access to market price information, strengthening farmer groups, and improving breeding services through artificial insemination and reproductive management. These strategies are important to improve income, maintain economic efficiency, and support buffalo population sustainability. Future studies are recommended to examine the nutritional quality of local feed resources, the effectiveness of feed preservation technology, and the long-term impact of breeding and market interventions on smallholder buffalo farming performance.

AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the authors used Grammarly to assist with grammar checking, language editing, translation, and improving academic English writing. All outputs generated by these tools were carefully reviewed, verified, and revised by the authors to ensure the accuracy, clarity, and appropriateness of the content. The authors take full responsibility for the integrity, originality, and final content of this manuscript.

DATA AVAILABILITY

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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