PERFORMANCE ANALYSIS OF THE CATTLE FARMING INDUSTRY IN SABAH: PRODUCTIVITY CONSTRAINTS, INSTITUTIONAL SUPPORT, AND PATHWAYS TOWARDS BEEF SELF-SUFFICIENCY

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ABSTRACT

Cattle farming is very important to the food security, rural livelihoods and agricultural development in Malaysia. In spite of a number of government initiatives to boost domestic beef production, Malaysia remains very reliant on imported beef products to meet the domestic demand (Department of Veterinary Services [DVS], 2023). Sabah has good land potential and climatic suitability for livestock production, but still has not become self-sufficient in beef production. The objective of this research was to assess performance of cattle farming industry in Sabah through studying the aspects of production efficiency, productivity constraints, contribution of smallholder farmers and the role of government assisted farms in improving beef production locally. A quantitative research design was used, including cattle farmers in all parts of Sabah. There were descriptive and inferential statistical analysis to investigate the correlation between breeding management, feed availability, farmer training, support of institutions and production performance. The results have revealed the significant influence of breeding quality, feed resources, technical knowledge and institutional assistance on the productive performance of cattle. Beef production, largely from smallholder farms, is a significant source of beef for local markets, but these producers are constrained in their ability to expand production by a number of structural issues. The study suggests an in-depth livestock development framework which includes the integration of the use of technology, capacity building of farmers, improved breeding programmes and sustainable farming practices. The results have important policy implications for the organizers and planners of strengthening livestock sector and minimizing reliance on imported beef in Malaysia.

Keywords: Beef Cattle Production, Livestock Sustainability, Food Security, Self-sufficiency, Agricultural Development and Sabah.

INTRODUCTION

The food security challenge is a big issue now around the world because of population growth, urbanisation, climate change, and rising demand for animal-source protein (ASPs; FAO, 2023). The livestock industry is critical for food security and rural economic development in Malaysia, providing animal protein as well as income for farmers (OECD-FAO, 2024; Rathakrishnan et al., 2022). The

demand for beef products has also grown in the country due to changes in dietary preferences and rising incomes (FAO, 2023).

The production of beef remains below the domestic demand, leading to the continued reliance on imported beef and buffalo meat (DVS, 2023; OECD-FAO, 2024), despite its increasing consumption. Overall, Malaysia's beef self-sufficiency level is still below the other livestock subsectors, indicating the continued production challenges in the beef sector (DVS, 2023).
Sabah has a large land area that is suitable for livestock, and opportunities for integration of livestock in oil palm farms exist, with good potential for cattle production (DVS 2023). Despite this, local production remains outpaced by demand due to issues of breeding efficiency, availability of feed, use of technology and farm management practices (Mohd Saufi et al., 2023; FAO, 2023). Thus, the study focussed on the performance of the cattle industry in Sabah and the possible ways to make it more productive and achieve self-sufficiency in beef production.

Research Objectives
The objectives of this study are:

1. To examine the current performance of beef cattle production in Sabah.
2. To investigate factors contributing to low beef self-sufficiency levels.
3. To assess the contribution of smallholder cattle farmers to local beef production.
4. To evaluate the effectiveness of government-supported farms and institutional interventions.
5. To propose strategies for enhancing productivity and sustainability within the cattle industry.

LITERATURE REVIEW

1. Theoretical Foundation

The study is based on the theories of Agricultural Production Theory and Sustainable Livestock Development Theory. Agricultural Production Theory is the theory that discusses how production outputs are affected by the efficient use of production factors such as land, labour, capital, technology, and management. Productivity can be influenced by a combination of biological, economic, environmental and managerial factors that influence production efficiency in livestock systems (FAO, 2023; World Bank, 2022). Better management of these inputs can increase farm profitability and performance.

Sustainable Livestock Development Theory builds on this by focusing on the synergy between economic development, environmental responsibility and social welfare. Sustainable livestock systems should be economically viable, foster resource protection and protection of rural livelihoods (OECD-FAO, 2024; FAO, 2023). The theoretical perspectives offer a framework to

help understand the factors that affect the performance of cattle farming in Sabah.

2. Beef Production and Food Security

Food security is a priority policy issue as a result of the expansion in populations, changes in consumption habits and the increased demand for animal protein (FAO, 2023). In livestock production, self-sufficiency in beef is seen as a key indicator of national food security, as it indicates the ability of local production systems to supply the population's needs for beef (DVS, 2023).

The demand for beef has been seen to rise in recent years, and the production in the country is gradually growing, but this growth is slow, leading to the continued dependence on imports (OECD-FAO, 2024). The situation is the same in Malaysia where domestic beef production is not enough to meet the demand in the market. As a result, enhancing the productivity of cattle has emerged as a key priority to increase food security and decrease reliance on imports (FAO, 2023; DVS, 2023).

3. Challenges in Cattle Production

Livestock productivity and competitiveness have been found to be constrained by several factors, as evidenced by recent studies (FAO, 2023; OECD-FAO, 2024).

Limited Breeding Stock

Quality breeding stock is scarce, continuing to be a significant challenge for breeding herd expansion and genetic improvement. Limited access to improved genetic resources can lead to poorer reproductive function and slower productivity growth among farmers (FAO, 2023; DVS, 2023).

Feed Resource Constraints

Shortages of feed or rising feed prices have a significant impact on production efficiency. The increased reliance on bought feed and limited forage availability during different seasons of the year lead to higher operation costs and lower profitability (OECD-FAO, 2024; FAO, 2023).

Technical Knowledge Deficiencies

Farmer knowledge is of great importance in livestock management. Studies have shown that training, skills development and provision of advisory service are factors that facilitate the adoption of innovative practices and boost production performance (World Bank, 2022; FAO, 2023).

Animal Health Issues

Outbreaks of disease, poor biosecurity and restricted access to veterinary assistance are still

impacting livestock productivity and animal welfare. Effective disease management is still vital to minimising losses and maximising herd performance (WOAH, 2024; FAO, 2023).

Market Inefficiencies

Smallholder farmers have limited bargaining power and poor market coordination leading to low profitability. It is important to enhance market linkages and make the production chains more efficient to support the development of the industry (OECD-FAO, 2024; World Bank, 2022).

4. Smallholder Farmers' Share in the Agriculture Sector's Value Chain

Smallholder farmers still play important roles in cattle production and in rural livelihoods and local beef production in Sabah (DVS, 2023). Most run small scale businesses with little resources and are restricted in financing, technology adoption, extension services and other dimensions (FAO, 2023).

However, smallholders have a lot of potential to boost domestic beef production under these limitations. Research shows that strengthening training, technology availability, financial support, and veterinary services can have a significant impact on productivity and profitability (World Bank, 2022; Rathakrishnan et al., 2022). Capacity building of smallholders will thus continue to be an essential element of livestock development programmes.

5. Government intervention and institutional support

The role of government in supporting livestock development by breeding programmes, farmer training, veterinary services, infrastructure development and financial assistance is very important (DVS 2023). They are designed to boost productivity, boost food security and being more competitive in the industry.

Extension services and capacity building programmes support farmers to implement improved management practices and modern technologies, which help to improve production outcomes (FAO, 2023; World Bank, 2022). Research institutions also engage in innovation, technology transfer and applied research to help the industry in its development.

But to sustain growth, the programme needs to be implemented effectively, involve stakeholders and be monitored on an ongoing basis. To enhance the effectiveness of programmes and facilitate long-term development of Sabah's cattle industry, efforts are needed for greater cooperation and collaboration between government agencies, researchers, private sector organisations and the cattle farming community (OECD-FAO, 2024; FAO, 2023).

METHODOLOGY

Research Design

The study was a quantitative cross sectional research design, used to assess the performance of the cattle farming industry in Sabah and to determine factors that affect the performance of cattle production and self-sufficiency of beef production. Choosing a quantitative approach was appropriate because it allows for data to be collected and analyzed numerically for the objective analysis of relationships between variables and the production of statistically sound results (Hair et al., 2022; Saunders et al., 2023). This approach can be used to determine industry-wide trends and production related concerns over a more significant population.

The cross sectional design was adopted as it involved collecting data from the respondents at one time, thereby giving a picture of current farming practices, challenges encountered and perceptions of support for institutionalization in the cattle industry. In addition, this method allows for easier cross comparisons between the various types of farmers and has reduced resource demands compared to the longitudinal studies (Saunders et al., 2023).

This study focused on the impact of breeding management, availability of feeds, training access and institutional support on production performance. They were chosen because of recent literature focusing on their relevance in relation to livestock productivity and agricultural development (FAO, 2023; OECD-FAO, 2024).

Population and Sampling

The total population of the study were registered cattle farmers in Sabah who were selected as they were directly involved in cattle farming and management activities. Sabah was selected due to its large role in the livestock industry of Malaysia and its ability to aid in the nation's target of achieving national self-sufficiency in beef production (DVS, 2023).
A purposive sampling method was used to select respondents who had a good knowledge and experience in cattle farming practices (Saunders et al., 2023). This strategy provided coverage by farm size, production system and geographic area. The total number of farmers surveyed is 125, of which the small-scale farmer group are the largest group, in line with the structure of the cattle industry in Sabah where most operations are smallholders.

Table 1. Respondent Distribution

Category	Frequency	Percentage (%)
Small-scale Farmers	85	68.0
Medium-scale Farmers	28	22.4
Large-scale Farmers	12	9.6
Total	125	100.0

The inclusion of diverse farming categories enabled meaningful comparisons across operational scales and enhanced the representativeness of the study findings.

Data Collection

The data were collected from the cattle farming operations, production performance and factors affecting the productivity of the farm by using the structured questionnaire. The questionnaire method was chosen due to the fact that it is a standardised method of collecting data with a relatively large sample and that the answers are standardised (Hair et al., 2022).

The instrument had five parts: 1) demographic information about the respondent, 2) information about the farm, 3) production performance, 4) institutional support, and 5) perceptions about the status of beef self-sufficiency. To ensure clear, reliable and appropriate items on the questionnaire, a pilot test was conducted before the main survey. Modifications and changes were done in accordance with the feedback received from the participants.

Apart from the primary information, secondary information was sourced from government reports, livestock statistics, policy documents and peer reviewed publications. Multiple data sources were incorporated, which further enhanced the credibility of the findings, and give a wider picture on the cattle production issues in Sabah (FAO, 2023; DVS, 2023).

Data Analysis

Data collected were analysed by the Statistical Package for Social Sciences (SPSS). Statistical analysis was used to summarise the characteristics of the respondents, explore the relationships between the various variables and to determine the factors that can affect the production performance of cattle. The SPSS software made it easier to handle the data and allowed for thorough quantitative analysis (Hair et al., 2022).

Demographic characteristics, farm profiles and farm production indicators were initially summarized using descriptive statistics, which included frequencies, percentages, means and standard deviations. Correlation analysis was then done to find out the strength and direction of relationship among the independent variables and production performance.

Multiple regression analysis was done to further look at the determinants of productivity. The technique is used to measure the contribution of several independent variables to the variations in a dependent variable and is widely used in agricultural and social science research (Hair et al., 2022; Saunders et al., 2023). Production performance was the dependent variable for this study, and breeding management, feed availability, and institutional support as well as training access were the predictors.

The regression model is expressed as follows:

$$\text{Production Performance} = \beta_0 + \beta_1(\text{Breeding Management}) + \beta_2(\text{Feed Availability}) + \beta_3(\text{Training Access}) + \beta_4(\text{Institutional Support}) + \varepsilon$$

The results provided empirical evidence regarding the factors influencing cattle production performance and supported the achievement of the study's research objectives.

FINDINGS AND ANALYSIS

Respondent Profile

The demographic characteristics of the respondents were provided to give some indication of the demographic profile of the cattle farmers in Sabah. The results reveal that majority of the respondents had over 10 years of farming experience which reflects their heavy experience in livestock practices. This experience is beneficial in the feeding, breeding, health-care and marketing of these animals, especially in different environments and production settings. Adaptive management of cattle farming also allows farmers to implement adaptive management strategies that can contribute to the sustainability of the farm and its productivity (DVS, 2023).

Although there was a great deal of practical experience, respondents' educational background indicated a relatively low level of formal education. Over half possessed secondary education, and a minority had attended university and acquired a diploma or degree qualification.

Table 2: Educational Background of Respondents

Education Level	Percentage (%)
Primary School	24.8
Secondary School	53.6
Diploma	14.4
Degree	7.2

The results indicate that 'on the job experience' can sometimes be a substitute for lack of formal training. But an inability to use modern technologies, digital record-keeping and advanced management practices could be limited in lower education levels. Recent research has shown that training, knowledge acquisition and ongoing capacity development is an important factor in facilitating technology uptake and farm productivity of livestock farmers (FAO, 2023; OECD-FAO, 2024). Thus, the importance of improving training programs is continuously emphasized to increase farmers' managerial skills and to promote the industry modernization.

Production Systems Practiced

The study found that there is significant differences between the production systems used by

the cattle farmers in Sabah. Farmers' practices varied with consideration of their available land, capital and labor resources, and management goals. The result shows that traditional grazing is the most common production system, followed by semi intensive, intensive feedlot and integrated system of cattle-oil palm production.

Table 3: Production Systems

System	Percentage (%)
Traditional Grazing	42.4
Semi-Intensive	36.0
Intensive Feedlot	13.6
Integrated Oil Palm System	8.0

Traditional grazing systems remain the predominant systems because they involve only minimal investment and rely on pasture resources that are available. This is especially appealing to smallholder farmers who have limited finances and work on a part-time basis. Natural grazing can however lead to seasonal feed shortages, unpredictable nutritional intake and reduced growth performance of livestock. This means that the production efficiency with traditional management is lower than with more structured management.

In a semi-intensive system, both grazing and feeding are utilized, giving the farmer more control over nutrition and productivity of the animals. Highly concentrated feedlot systems show greater production efficiency, however, but have significant infrastructure, feed acquisition and labour management costs. The integrated of cattle-oil palm, although being adopted by a relatively small percentage of respondents, has huge potential for sustainable livestock development. It is a combination of livestock production and plantation management which increases the efficiency of land use, lowers the cost of maintaining vegetation control and provides extra income. The implementation of integrated farming systems could hence play a vital role in enhancing the productivity of cattle and sustainability of the cattle industry for the long run in Sabah.

Production Performance

A production performance assessment was carried out to assess the status of the cattle farming operations by the respondents. Herd size and calving rate, mortality rate, and sales revenue per year were analysed. These indicators are significant indicators of farm productivity, reproductive efficiency, and economic performance.

Table 4: Key Production Indicators

Indicator	Mean
Herd Size	18 heads
Calving Rate	58%
Mortality Rate	7.8%
Annual Sales	RM42,500

The results show high levels of variation in farmers' production performance. The average herd size of 18 heads is indicative of the small scale farming operation in Sabah cattle industry. A handful respondents had relatively large commercial herds, but most had relatively small livestock enterprises. Calving rate is also below optimum with an average of 58 percent. Beef production systems in other countries often show a high percentage of calves born (75 percent or more), suggesting that there are ways to improve the calving percentage through better breeding management, nutrition and reproductive monitoring.

The 7.8 percent mortality rate further suggests challenges to herd health and survival that need to be resolved through management. Livestock losses could be due to disease outbreaks, poor veterinary care, poor nutrition, or environmental stress. Lowered mortality rates may have significant impact on overall productivity and profitability.
Cattle farming is also important to rural households and is an important source of income as reflected in annual farm sales which averaged RM42,500. But, there was significant variation in revenue depending on herd size, production system and market access. The results demonstrate that there is significant potential for productivity growth from better management, new technologies and institutional support. Improving reproductive efficiency and minimizing animal losses should therefore be seen as priorities in development programmes of the industry.

Correlation Analysis

To study the relationship between selected independent variables and production performance of cattle, correlation analysis was done. The strength and direction of association between the variables were determined using Pearson's correlation coefficient.

Table 5: Correlation Matrix

Variable	Productivity (r)
Feed Availability	0.72
Training Access	0.69
Breeding Quality	0.75

Institutional Support	0.64

The findings suggest positive correlation between all the independent variables and production performance. In this context, the breeding quality had the highest correlation with productivity (r = 0.75), which indicates that good genetics and good management of the reproduction process are very important to the performance and production efficiency of a herd (FAO, 2023; DVS, 2023). The availability of feed was also highly correlated with productivity (r = 0.72), indicating that proper feed is crucial for animal growth and reproductive performance (OECD-FAO, 2024).

Knowledge and skills development positively correlated with productivity (r = 0.69), implying that the more a farm is able to access training, the more effective it is in managing the farm (World Bank, 2022). Extension services, veterinary support and development programmes were found to be contributing to production improvement and have the lowest but still high correlation (r = 0.64) was recorded in this study for institutional support. These results are aligned with recent investigations, which have highlighted the importance of livestock productivity factors, such as breeding, nutrition, human capital and institutions (FAO, 2023; OECD-FAO, 2024).

ADVANCED STATISTICAL ANALYSIS AND HYPOTHESIS TESTING

Multiple Regression Analysis

Multiple regression analysis was used to determine the factors affecting the production performance of the cattle in Sabah. The dependent variable was production performance, and the independent variables were breeding management, the availability of feeds, access to training and institutional support.

Table 7: Multiple Regression Results

Variable	Beta (β)	t-value	p-value
Breeding Management	0.381	5.892	0.000
Feed Availability	0.294	4.765	0.000
Training Access	0.216	3.918	0.001
Institutional Support	0.178	2.863	0.005
Constant	1.427	2.115	0.037

$R^2 = 0.672$, Adjusted $R^2 = 0.658$, $F = 48.326$, $p < 0.001$

About 67.2% of the variation of production performance can be explained by the model of the regression. This shows a high explanatory value and that the variables chosen play an important role in the outcomes of cattle farming.

Breeding management was the most important variable in the prediction of productivity. Based on this discovery, it is hoped that the beef production in Sabah could be significantly enhanced through genetically improving their breeding programmes, quality of their genetics and their herd replacement policies.

The second greatest determinant is feed availability. The findings support earlier research that found that feed shortage is one of the most important factors that restrict the productivity of livestock in tropical production systems.

Additionally, there were statistically significant effects for training access and institutional support. The results of this research reflect the continued need for human capital development and government interventions to promote industry's progress.

Hypothesis Testing

H1: The level of breeding management is significantly related to the level of the cattle production performance.

The coefficient of the regression resulted positive ($\beta = 0.381$, $p < 0.001$).

Decision: Supported.

This indicates that with good breeding management there is a considerable contribution to production performance. The farmers who adopt controlled mating systems, superior breeding stock selection and reproductive monitoring attain higher productivity than those farmers who consider only traditional breeding practices.

H2: Feed availability has a strong relationship with performance of cattle production.

The productivity was positively correlated with the availability of feed ($\beta = 0.294$, $p < 0.001$).

Decision: Supported.

The discovery also shows that the amount of feed available has a direct impact on the growth of the animal, reproductive efficiency and overall productivity of the herd.

H3: The access to training has a significant impact on the performance of cattle production.

The training access had a significant positive effect ($\beta = 0.216$, $p = 0.001$).

Decision: Supported.

Farmers that were trained in the programmes, indicated better management practices, better record keeping and better adoption of modern technologies of production.

H4: Support to the cattle production has a significant impact on the performance of cattle production.

This was also found to be statistically significant ($\beta = 0.178$, $p = 0.005$) in institutional support.

Decision: Supported.

The Government agencies remain significant in providing technical assistance, infrastructure and knowledge transfer programmes to support the development of livestock.

DISCUSSION

Structural Characteristics of the Sabah Cattle Industry

The Sabah Cattle Industry is characterized into six broad areas as follows:

The results suggest that the cattle industry in Sabah is largely smallholder and the farmers' financial capacity and herd size is low. This production system is foundational and it puts constraints on economies of scale, which makes investments in modern technologies, infrastructure and productivity enhancing practices (DVS, 2023; FAO, 2023) difficult. The lack of coordination in the supply chain due to fragmented production systems also leads to inefficiencies in marketing and lead to variable product supply. Small-scale operations are reported to persist for many livestock activities in developing areas, impacting competitiveness and market integration, (OECD-FAO, 2024). Ensuring better market access, operational

efficiency, and sustainability of the industry is through strengthening producer cooperatives and supporting the farming model based on clusters (World Bank, 2022).

Breeding Challenges and Herd Productivity

Breeding management came out as the most influential factor that affects the productivity of the cattle in Sabah. Good herd management practices enhance the reproductive efficiency, growth rate and herd performance that directly translate into increased beef production (FAO, 2023; DVS, 2023). There are a number of locally produced breeds of cattle which are very tolerant of tropical conditions but are less productive than improved, crossbreed individuals. A large number of farmers still use natural mating and have low level breeding records thus limiting the progress of the herd and genetic improvement of the farm. Artificial insemination (AI) services and systematic breeding programmes can be expanded and farmer training can be done to boost reproductive performance, improve herd quality and contribute to Malaysia's strategy to improve domestic beef production and self-sufficiency (OECD-FAO, 2024; World Bank, 2022).

Feed Constraints and Production Efficiency

A shortage of feed remains to be a significant restriction on the productivity of cattle in Sabah. Forage availability fluctuates with the seasons, causing a drop in feed available and a reduction in the nutritional value of the forage, which affects animal growth, reproduction and productivity of the herd (FAO, 2023; DVS, 2023). Agricultural by-products and natural pasture continue to be used by many smallholder farmers and these are not necessarily balanced with all the nutrients needed for optimum livestock production. This consequently, can result in high cost of production and reduce profit of the farm if inadequate feed is available.

The integrated cattle-oil palm system has proven to be a good alternative to enhance feed availability and land-use efficiency. Recent research has shown that the integration of livestock into plantain systems can be a positive development that can increase the utilisation of the forage, help to ensure sustainable resource management and improve production without the need to expand agricultural land (Rahman et al., 2021; OECD-FAO, 2024). In addition, forage production, forage preservation methods and technologies, production of silage and alternative feed resources can support the feed security all year round. Therefore, it is crucial to manage the nutrition of cattle and reinforce the feed supply system to increase productivity, build farm resilience and ensure the sustainability of the cattle industry in Sabah (FAO, 2023; World Bank, 2022).

Human Capital Development

Positive correlation between the access of training and production performance shows the importance of human capital development. Generally, farmers who have been involved in trainings are more competent in nutrition management, breeding and disease prevention

(FAO, 2023; DVS, 2023). Technical knowledge helps to make better decisions, utilize resources better. As livestock production becomes increasingly technologically based, continuous learning is a must. Digital learning platforms, online advisory services, and mobile applications can supplement existing extension programmes and enhance information and communication, especially for farmers in rural areas (World Bank, 2022; OECD-FAO, 2024).

Institutional Support and Industry Development

Breeding programmes, farmer training, veterinary services and infrastructure development (DVS) are all important measures that can be taken to improve the productivity of livestock production, and these measures are greatly supported by institutions. Farmers taking advantage of government programmes tend to have better production results and show a higher level of uptake of new practices (FAO, 2023). However, the effective implementation, sufficient funding, involvement of stakeholders and ongoing programme assessment are all essential elements of sustainable development (OECD-FAO, 2024). Cooperation between relevant government agencies, research agencies, private sector and farms to boost innovation, productivity and achieve self-sufficiency goals is thus essential for achieving self-sufficiency in beef in Malaysia (FAO, 2023; World Bank, 2022).

POLICY IMPLICATIONS

Strengthening Breeding Programmes

Policymakers should focus on breeding improvement programmes and increase farmers' access to high-quality breeding stock and reproductive technologies. Increased capital investment in artificial insemination, genetic evaluation systems and nucleus breeding farms will help to increase the reproductive efficiency and the productivity of the herd. Meanwhile conservation of local cattle breeds is also relevant for their adaptation to local climatic conditions, disease problems (FAO, 2023; DVS, 2023).

Enhancing Feed Security

Feed security needs to be improved through ongoing investment in forage development, feed conservation technologies and other feed resources. Feed processing plants and silage production centres can help to minimize feed shortages in the season and ensure a more stable feed situation for livestock. These measures can contribute to improving animal performance, reducing production costs and increasing the profitability of farms, and help build the resilience of the industry into the future (FAO, 2023; OECD-FAO, 2024).

Expanding Extension Services

Extension services need to be expanded beyond area of scope and farmers need to be contacted more often. Technical abilities with breeding, nutrition and herd management can be enhanced by training programmes, field demonstrations and advisory support. More extension services would enable better farming practices to be adopted and help to boost productivity (World Bank, 2022; DVS, 2023).

Promoting Technology Adoption

Modern technologies can be a great help in improving the efficiency of the operations and farm management. Use of digital record-keeping systems, precision feeding technologies and livestock monitoring can be promoted through financial incentives, grants and subsidised programmes. Incorporating technology helps with improved decision making, utilization of resources and competitiveness of the industry (FAO, 2023; World Bank, 2022).

Improving Market Coordination

Building up producer cooperatives and farmer associations can help provide better market access and farmer bargaining power. Greater collaboration between producers, processors and retailers would enhance the efficiency of supply chains, lower transaction costs and increase price transparency. This co-operation could lead to a more stable market opportunity and help to improve the sustainable income of livestock producers (OECD-FAO, 2024; World Bank, 2022).

PROPOSED SMART FARMING FRAMEWORK FOR SABAH

To achieve sustainable growth, the cattle industry should progressively adopt smart farming technologies.

Conceptual Smart Farming Framework

Input Layer:

- Breeding stock
- Feed resources
- Veterinary services

Technology Layer:
- RFID animal identification
- Digital herd management
- Precision feeding systems
- Remote monitoring sensors

Management Layer:
- Data-driven decision making
- Performance monitoring
- Predictive disease management

Output Layer:
- Increased productivity
- Improved animal welfare
- Enhanced profitability
- Higher self-sufficiency

This framework integrates technological innovation with traditional livestock management practices to improve overall system efficiency.

SUSTAINABILITY FRAMEWORK FOR SABAH'S CATTLE INDUSTRY

In order to reach sustainable growth in the cattle industry in Sabah, a balanced approach for economic, environmental and social goals are required. Modern livestock development goes beyond the mere expansion of livestock production and integrates profitability, resource management and community well-being to ensure sustainability and food security in the long-term (FAO, 2023; OECD-FAO, 2024). The incorporation of these aspects is crucial to further enhance the industry competitiveness and sustainability.

In economic terms, sustainability is about improving farmer profitability, improving production efficiency and decreasing operating costs. With advancements in breeding management, nutrition, and farm practices, better productivity and profitability can bring additional opportunities for farmers to invest in innovation and business expansion (DVS, 2023; FAO, 2023).

The environmental dimension is on efficient usage of resources and environmentally friendly production systems. Farmers have been interested in integrated cattle-oil palm farming, which combines production of both crops to make better use of land and to increase the supply of forage for cattle, to ensure better resource management, while reducing negative consequences on the environment (Rahman et al., 2021; FAO, 2023).

Social dimension focuses on job creation, livelihood development in rural areas and food security. Livestock production plays a role in local economic development by providing income and livelihoods and fostering local community resilience (Rathakrishnan et al., 2022; OECD-FAO, 2024). It is therefore essential for the cattle industry in Sabah to be both economically efficient and sustainable towards the environment and social development to ensure sustainability of the industry in the long run.

THEORETICAL CONTRIBUTIONS

In this study, the authors have added institutional support and human capital as crucial factors affecting cattle productivity to Agricultural Production Theory, thereby enriching it. The results show that the competencies of farmers, technical training and farmer access to support services are important factors that affect farmers' production performance, in addition to the conventional production factors like land, labour, and capital (FAO 2023; World Bank 2022). The study further substantiates the Sustainable Livestock Development Theory by offering empirical evidence that shows that the economic viability, the management of resources and the capacity development all play a role in shaping the sustainability of the livestock sector in developing economies (OECD-FAO 2024; FAO 2023). Moreover, this research filled a significant gap in the existing research on livestock productivity in Malaysia, as it provided an all-encompassing review of livestock productivity constraints, practices and development opportunities in the cattle industry of Sabah. The results help deepen the understanding of the relationship of institutional and managerial aspects in determining agricultural performance and in providing evidence for policy formulation for sustainable livestock development (IPCC, 2023; DVS, 2023).

PRACTICAL CONTRIBUTIONS

The results can be used to gain insight into several sectors related to livestock development. The study underscores the significance of sound breeding techniques, feed management, and ongoing training for farmers to enhance their productivity. The results can be used by government agencies to develop specific interventions to tackle specific industry constraints such as feed supply, genetic improvement and extension services (DVS, 2023). The findings also highlight potential investment opportunities for integrated farming systems of cattle and oil palm, and technology-based livestock businesses. Additionally, the study offers researchers valuable information for future research on sustainable livestock production, rural development and agricultural transformation in Malaysia and other developing economies.

LIMITATIONS OF THE STUDY

Some restrictions must be kept in mind with regard to the results. The study used the cross sectional research design, which only allows one to get a snapshot of the situation at one particular moment in time, and does not allow for the determination of causal relationships between variables (Saunders et al, 2023). This is helpful when studying existing conditions of an industry, but fails to account for improvements in industry production over time. Secondly, the study was carried out in specific districts of Sabah, which might limit the generalizability of results of the study at the national level of cattle farming in the state. The results might be different across various locations due to the differences in farm size, production systems and geographical conditions (DVS, 2023). Third, third-party information was used to determine some of the production indicators, which may have experienced recall biases and inaccuracies in self-reports (Hair et al., 2022). More studies should have objective farm performance data, larger sample sizes and employ longitudinal designs to strengthen the robustness of future studies, providing improved reliability, validity, and wider applicability of their findings (FAO, 2023; World Bank, 2022).

FUTURE RESEARCH DIRECTIONS

Several areas of potential research could be considered to enable sustainable growth and competitiveness of cattle industry in Sabah. Economic assessments of the cost-effectiveness and potential for adoption of smart livestock technologies, such as precision feeding systems, automated health monitoring and sensor-based herd management, would be helpful to gain information on their feasibility and usefulness to farmers (FAO, 2023). The economic, environmental, and production returns of integrated cattle-oil palm production systems need to be determined, especially in the face of evolving farming and market contexts (Rahman et al., 2021). Research on adaptation and mitigation is crucial to increase the resilience of livestock sector to the impacts of climate change, which continue to manifest in the industry through heat stress, prevalence of diseases, and availability of feed (IPCC 2023).

Furthermore, consumer behaviour studies are needed to focus on preferences, purchasing intentions and willingness to pay for locally produced beef to support the development of the local markets (OECD-FAO, 2024). Studies of genetic improvement programmes for tropical cattle breeds can help in identifying breeding programmes that can increase productivity, adaptability, and disease resistance for local situations (FAO 2023). In addition, research must be conducted on the digital transformation of livestock value chains, such as traceability systems and decision-making tools based on information, which could contribute to increasing the efficiency and transparency of the sector (World Bank, 2022). The comparative analyses of the results between the cattle producing areas in Sabah and other areas would provide further evidence-based information for policy formulation and sustainable development of livestock.

CONCLUSION

The agri-cattle sector in Sabah has great potential to help accomplish Malaysia's food security goals. The results, however, suggest that significant structural bottlenecks still exist that restrain production performance and self-sufficiency results. Breeding management, feed availability, farmer training and institutional support were found to be important factors influencing productivity. Breeding management had the strongest influence and it therefore emphasizes the need for genetic improvement and reproductive efficiency among these. While smallholder farmers encounter several operational difficulties, they are still key to industry development. Government support for farms and institutional interventions offer a positive contribution to industry development, but still have some way to go in terms of improvements to implementation. The study demonstrates that a concerted effort in technology, people, resources, and partnerships between the public and private sectors is needed to achieve greater beef self-sufficiency. Integrated livestock development system and the use of smart farming technologies can help to bolster the country's cattle industry, minimise the reliance on imports, and play a more meaningful role in the nation's food security objectives in the future.

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