

Data-Driven Assessment of Beef Cattle Management Practices for Sustainable Livestock Systems in Smallholder Farming

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Abstract

A sustainable livestock breeding system, as mandated in Indonesian Ministry of Agriculture Regulation No. 46/Permentan/PK.210/8/2015, requires integrated management of feeding, housing, breeding, health, and maintenance. However, implementation at the smallholder level remains inconsistent. Rumbio Jaya District is a major beef cattle production area where data-driven evaluation is needed to support sustainable development. This study adopts a data analytics perspective aligned with AI for Sustainability and Social Impact. A survey was conducted from March to April 2023 involving 142 farmers managing 993 cattle. Data were collected through structured interviews and field observations, then analyzed descriptively to evaluate key technical aspects, including breeding selection, housing, feeding, maintenance, and animal health management. The results show moderate implementation in breeding (50.26%), housing (56.91%), feeding (51.64%), and maintenance (69.95%), but low performance in animal health (19.28%). These findings indicate critical gaps that may reduce productivity and resilience of the farming system. A data-driven approach can support better decision-making and targeted interventions. In conclusion, beef cattle

management practices in Rumbio Jaya District do not fully meet national standards. Integrating data analytics into livestock management can improve efficiency, sustainability, and farmer outcomes.

Keywords

beef cattle, data analytics, sustainability, smallholder farming, livestock management.

1. Introduction

Riau Province has experienced significant growth in the beef cattle sector over the last few years. The beef cattle population reached 202,647 head in 2020, representing a 21.85% increase compared to the previous year. Beef production also increased to 8,611 tons during the same period (BPS, 2023). Despite this positive trend, regional beef demand is projected to reach 19,480 tons annually by 2024, indicating a substantial gap between domestic production and consumption requirements. This condition highlights the urgent need for effective and sustainable strategies to strengthen beef cattle productivity and regional food security. Kampar is recognized as one of the major beef cattle production centers in the province. The regency possesses considerable natural resource potential, particularly through the integration of cattle farming with oil palm plantations that can function as alternative feed resources. In addition, its strategic proximity to Pekanbaru facilitates livestock distribution and market access. Among the potential livestock development areas in the regency, Rumbio Jaya District is characterized by abundant feed availability and favorable environmental conditions for beef cattle farming. However, the beef cattle population in Rumbio Jaya District declined substantially from 1,051 head in 2020 to 510 head in 2022 (BPS, 2023). This decreasing trend suggests the presence of structural constraints within the livestock production system, particularly related to the implementation of technical husbandry practices. Therefore, systematic evaluation is required to identify critical constraints affecting cattle productivity at the farmer level. Along with the rapid development of Artificial Intelligence and data analytics, data-driven approaches have become increasingly important in agricultural and livestock management. Quantitative field-based evaluations can provide objective insights into the implementation level of technical husbandry practices and support more precise and adaptive decision-making processes. Accordingly, this study aims to systematically evaluate the implementation of technical aspects of beef cattle husbandry in Rumbio Jaya District using a data-driven approach. The findings are expected to strengthen farmer knowledge, improve management practices, and support sustainable beef cattle production systems.

1.1 Objectives

This study aims to systematically and data-drivenly evaluate the implementation of technical aspects in beef cattle husbandry in Rumbio Jaya District. The study results are expected to improve farmer knowledge, encourage changes in management behavior, and strengthen sustainable livestock production systems (10 font)

2. Literature Review

Technical aspects of livestock husbandry are recognized as the main determinants of productivity and sustainability in beef cattle farming systems. Several studies reported that breeding management, feeding systems, housing quality, animal health control, and farm management practices significantly influence reproductive efficiency, growth performance, and economic profitability in smallholder cattle production systems (Yendraliza et al. 2021a); (Indey et al. 2022). Riau Province possesses substantial potential for implementing integrated beef cattle production systems because of its extensive oil palm plantation areas. Nevertheless, several regions continue to experience declining cattle populations despite abundant feed resources. This condition indicates that resource availability alone is insufficient without proper implementation of technical husbandry practices and effective farm management systems. Previous studies emphasized that farmers' knowledge, management skills, and adoption of livestock technologies strongly influence production outcomes and farm sustainability. Research conducted by Yendraliza et al. (2021a) demonstrated that optimization of technical husbandry practices contributes significantly to improving beef cattle productivity in tropical production environments. The study highlighted that balanced feeding, proper breeding systems, adequate housing conditions, and preventive health management are essential factors for maintaining livestock performance and reproductive efficiency. Likewise, Indey et al. (2022) explained that technical implementation plays a central role in determining operational efficiency and sustainability of cattle farming enterprises. Data-driven evaluation is increasingly relevant for supporting sustainable livestock production systems, particularly in smallholder farming systems characterized by limited resources and heterogeneous management practices. Therefore, a systematic assessment of technical implementation is necessary to formulate effective strategies for improving productivity,

strengthening regional beef self-sufficiency, and supporting sustainable livestock development in tropical regions (10 font)

3. Methods

The study population comprised all beef cattle farmers in Rumbio Jaya District, totaling 142 respondents. Seven villages were included as sampling units, namely Alam Panjang, Batang Batindih, Bukit Keratai, Pulau Payung, Simpang Petai, Tambusai, and Teratak. A census approach was employed, ensuring that all eligible farmers within the study area were included as respondents. The research variables encompassed farmer characteristics and the implementation of technical aspects of beef cattle husbandry, as outlined in Indonesian Ministry of Agriculture Regulation No. 46/Permentan/PK.210/8/2015. These aspects included breeding selection, general management practices, housing systems, animal health, and feeding management.

4. Data Collection

Primary data were collected using structured questionnaires administered directly to respondents. Data analysis was conducted using descriptive statistics, specifically mean values and standard deviations. The level of implementation of technical practices was quantified using a scoring system and subsequently categorized into three levels: low (1), moderate (2), and high (3). The classification thresholds were determined based on the range formula proposed by Kusai, calculated as the difference between maximum and minimum scores divided by the number of categories. The maximum score was derived from the product of the number of items, respondents, and the highest possible score, while the minimum score was based on the lowest score. Scoring criteria were aligned with the ministerial regulation, where a score of three indicated optimal compliance, two represented moderate compliance, and one reflected low or inadequate implementation of the prescribed standards.

5. Results and Discussion

5.1 General Description of the Research Area

Rumbio Jaya District is an administrative sub-district within Kampar Regency, with its administrative center located in Teratak Village. The area spans approximately 76.92 km² and is geographically positioned between 01°05' South Latitude and 02°25' North Latitude, and around 100°05' East Longitude. It comprises seven villages and 45 hamlets, bordered by Tapung District to the north, Kampar District to the south, East Kampar District to the east, and North Kampar District to the west. The region experiences a tropical climate with an average annual rainfall of 283 mm (BPS, 2021). Topographically, the district is characterized by predominantly flat and swampy land at an elevation of about 40 meters above sea level. The presence of the Kampar River and several tributaries shapes the area's physical landscape. Rumbio Jaya District was established through the administrative division of Kampar District. Initially, it had a relatively small population; however, demographic growth has accelerated in line with regional development. Based on BPS data (BPS, 2023), the total population reached 18,862, consisting of 9,618 males and 9,244 females distributed across the seven villages. The district is recognized as a strategic livestock development zone, with Bali cattle as the dominant breed due to their adaptability to tropical conditions, resilience to disease, and compatibility with extensive management systems. Other breeds such as Rambon, Brahman Cross, Peranakan Ongole, Limousin, Simmental, and Friesian Holstein are present in smaller numbers. In 2022, the beef cattle population was recorded at 510 head (BPS, 2023). Despite adequate land and feed resources, livestock development remains constrained by traditional management practices, including uncontrolled grazing and limited application of feeding and reproductive management. These limitations contribute to suboptimal productivity, lower livestock quality, and increased vulnerability to animal health issues (Figure 1).

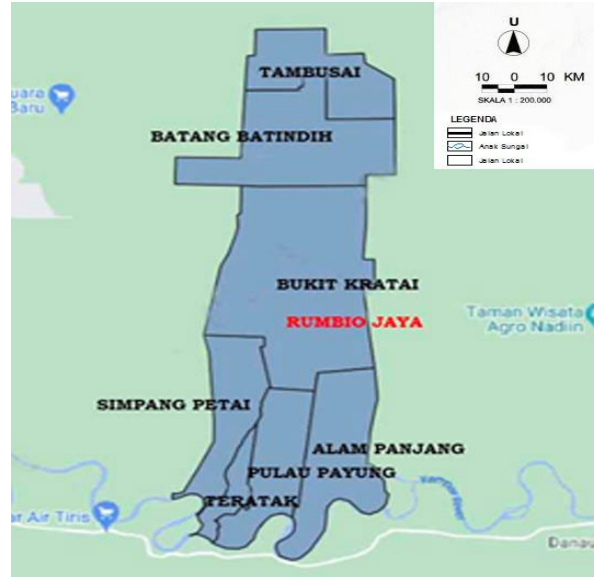


Figure 1. Map of Rumbio Jaya District

5.2 The breeder Profil

The profil breeder in Rumbio Jaya District is predominantly male and falls within the age range of 38 to 62 years. Most farmers have completed secondary education (high school) and possess between 5 and 8 years of experience in livestock production. These characteristics indicate that the majority of farmers are within a productive age group and have an adequate educational background. Previous findings by Yendraliza et al. (2020) suggest that farmers with productive age profiles and sufficient experience are more likely to achieve better livestock performance and contribute to increased herd productivity (Table 1).

Table 1. Socio-demographic characteristics of smallholder farmers (n=142)

Variable	category	n	Persentase (%)
Gender	Male	125	88
	Female	17	12
Age of farmers (years)	< 22	1	1
	< 30	7	5
	< 38	29	20
	39-46	37	26
	47-54	31	22
	55-62	23	16
	63-70	11	8
	>71	3	2
Formal education leve	No formal education	8	6
	Elementary school	41	29
	Junior high school	30	21
	Senior high school	57	40
	Higher education	6	4
Farming experience (years)	1-4	54	38
	5-8	45	32
	9-12	21	15
	13-16	13	9
	>17	9	9

Characteristics of breeders in implementing maintenance aspects

Breeding management among cattle breeders in Rumbio Jaya District remains at a moderate level. Field observations indicate that farmers apply a combination of reproductive practices, including natural mating, artificial insemination (AI) with relatively high success rates, and basic selection of breeding stock. These practices play an important role in improving both the genetic quality and population size of livestock. Moreover, effective breeding management contributes to national food security and enhances the economic returns of smallholder farmers (Yendraliza, et al. 2018a). However, key management components such as performance evaluation (judging) and systematic recording have not been implemented. This limitation is primarily due to a lack of awareness and technical knowledge regarding their importance in livestock improvement (Yendraliza et al. 2018b). In addition, the study revealed that farmers have not yet adopted replacement stock strategies. Replacement stock refers to animals selected to substitute breeding individuals with declining productivity or those no longer suitable for reproduction. These animals may be male or female, depending on herd requirements and breeding objectives (Kusuma et al. 2017) (Table 2).

Table 2. Implementation Level of Cattle Management Practices among Smallholder Farmers in Rumbio Jaya Sub-district

No	Management Aspect	Mean score ± SD	Implementation Level (%)	Category
1	Breeding management	4.02±1.77	50.26	Moderate
2	Housing management	5.11±2.87	56.9	Moderate
3	Feeding management	3.01±0.17	51.64	Moderate
4	General husbandry practices	4.2±0.84	69.95	High
5	Animal health management	2.42±1.25	19.28	Low

Note: Data are presented as mean ± standard deviation (SD). Categories were classified based on the percentage achievement score of each management aspect.

Housing Aspects

All cattle farmers in Rumbio Jaya District utilize housing systems for keeping their livestock. According to Indonesian Ministry of Agriculture Regulation No. 46/Permentan/PK.210/8/2015, proper cattle housing should be located separately from other livestock activities, constructed using durable and livestock-safe materials, and designed to facilitate easy cleaning. In addition, housing facilities should include adequate drainage and waste management systems, reliable access to clean water, proper ventilation, sufficient exposure to morning sunlight, and dimensions that correspond to the body size of the animals. Field findings indicate that the majority of existing cattle pens do not yet comply with the recommended dimensional standards outlined in the regulation. Furthermore, isolation pens are not available. In cases of illness, animals are not managed in designated isolation facilities but are instead separated and placed in open areas, often under oil palm plantations. Functionally, housing systems play a critical role in livestock management. Proper housing supports environmental control, particularly under fluctuating climatic conditions, and contributes to disease prevention, security against theft, and overall herd safety. In addition, well-designed housing improves management efficiency and reduces labor requirements (Yendraliza et al. 2021b).

Feeding Aspects

Feeding practices among cattle farmers in Rumbio Jaya District are still highly conventional. All beef cattle are fed exclusively with fresh forage, primarily grass, without any supplementation or mixed rations. The use of concentrate feed has not been adopted, and farmers generally do not formulate balanced rations for their livestock. This condition is largely influenced by the relatively high cost of concentrate feed, as well as limited knowledge regarding feed formulation and nutritional management. As highlighted by Afriani et al. (2019), the level of education significantly affects farmers' understanding of ration composition, appropriate feeding quantities, and the overall importance of proper feeding practices in improving livestock productivity.

Care Aspects

According to the Indonesian Ministry of Agriculture Regulation No. 46/Permentan/PK.210/8/2015, livestock husbandry systems are classified into three main categories: intensive, semi-intensive, and extensive. These systems cover various stages of animal care, including calves, weaners, heifers, pregnant cows, and animals designated for fattening. Standard management practices emphasize specific care for newborn calves, such as initial weighing and

identification within the first week of life. Calves are then maintained in individual pens up to one month of age, allowing adequate movement and exposure to morning sunlight. Introduction to forage begins at approximately three months, followed by weaning at six to eight months. In Rumbio Jaya District, the implementation of care practices is generally categorized as high. However, cattle farming is predominantly treated as a secondary activity rather than the main source of income. Farmers typically apply a semi-intensive system, where cattle are released for grazing during the day and returned to pens at night. While housed, animals are provided with forage and, in some cases, processed feed. Farmers recognize that proper management across all production stages can improve productivity, minimize losses, and enhance the quality of livestock products, as also reported by Fioretti et al. (2020).

Health Aspects

The findings show that the majority of farmers in Rumbio Jaya District have not yet implemented biosecurity measures in an optimal and consistent manner. Routine disinfection of workers, housing facilities, and equipment is rarely conducted. In addition, key preventive practices such as appropriate site selection for housing, quarantine of newly introduced animals, periodic emptying of pens, and segregation of sick and healthy animals are generally not applied. The absence of dedicated isolation facilities is a primary constraint, resulting in the lack of separation between diseased and healthy livestock.

Despite these limitations, no significant outbreaks of severe disease were reported among the herds. This condition is likely associated with the routine administration of vaccinations and vitamin supplementation by farmers as basic preventive measures. According to Directorate of Livestock Cultivation, biosecurity refers to a set of preventive strategies designed to minimize the risk of introduction and transmission of infectious agents within animal populations. These measures include maintaining sanitation of housing, equipment, and the surrounding environment, as well as implementing strict separation between new, sick, and healthy animals

6. Conclusion

In conclusion, the implementation of technical aspects of beef cattle management in Rumbio Jaya District has not yet fully complied with the standards outlined in Indonesian Ministry of Agriculture Regulation No. 46/Permentan/PK.210/8/2015. Although maintenance practices demonstrate relatively high performance, key components such as breeding, housing, and feeding remain at a moderate level, while animal health management is still critically low. These findings highlight significant gaps in the application of technical practices at the farm level, particularly in health and biosecurity measures, which may limit productivity and sustainability. A data-driven approach provides a clear basis for identifying these constraints and supports more precise, evidence-based interventions. Therefore, integrating data analytics into livestock management systems is essential to enhance decision-making, improve technical compliance, and promote sustainable beef cattle production in smallholder farming systems. (10 font)

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Biographies

Yendraliza is an academic and professor in animal science who serves as a lecturer at Sultan Syarif Kasim State Islamic University, Riau. She held leadership roles as Vice Dean for Academic Affairs (2013–2015) and Vice Dean for Student Affairs and Alumni (2015–2018). She earned her Bachelor's, Master's in Agriculture, and Doctorate in Animal Husbandry from Andalas University, Indonesia, and completed her professional engineering education (Ir) at the same institution. She is an active member of the Indonesian Engineers Association (PII), the National Association of Animal Reproduction and Breeding Experts (ARPENAS), the Indonesian Animal Reproduction Association (ARHI), and several women's organizations. Her teaching covers livestock physiology, genetics, reproductive biotechnology, and buffalo science. Her research focuses on animal reproduction, including sperm sexing technology, fertility of local breeds, and genetic resource development. She has produced numerous peer-reviewed publications and patent-oriented works. She also contributes as an editor of reputable international journals, a training facilitator, and a lead implementer of research-based community service programs in teacher development, community empowerment, and livestock technology-based entrepreneurship.

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