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Improving The Sustainability of Silage Adoption in Dairy Cattle Farming: Analysis of Determining Factors and Strategies for Increasing Farm Capacity

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Abstract

One of the challenges of dairy farming is the availability of feed to meet the needs of livestock. This study aims to 1) identify the potential and problems of utilizing local feed, as well as the potential for implementing silage development; 2) analyze factors that influence the adoption of locally sourced feed innovations; 3) develop strategies for sustainable adoption and increasing the capacity of dairy farmers. This study used a participatory approach involving 47 farmers as a two-year action study (2023–2024). Data collection methods include surveys, in-depth interviews, and focus group discussions (FGDs). Data was analyzed using Structural Equation Modeling-Partial Least Square (SEM-PLS) to identify factors that influence the adoption of silage innovations. The results of the study showed that the adoption of silage technology was influenced by the characteristics of farmers, the role of extension workers, and the nature of the innovation. Although the potential for local feed is abundant, its utilization is still low due to limited knowledge of farmers and processing infrastructure. The structural model test showed a significant relationship between silage adoption and increased milk productivity (coefficient 0.508; p = 0.008). This study recommends strengthening the institution of livestock farmers through the People's Livestock School (SPR), continuous training, and integration of crop-livestock systems (SITT) to optimize local resources. The proposed design model includes silage-based feed diversification, utilization of agricultural waste, and partnerships with agribusiness actors. This study provides a reference for sustainable agricultural policies and the development of technological innovations that are adaptive to the characteristics of smallholder farmers.

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1. Introduction

In dairy farming, feed presents a major challenge. It is a vital factor in enhancing livestock productivity, along with breeding and efficient management. Additionally, feed costs significantly influence production expenses (Amam & Harsita, 2019a). Indonesian livestock farmers have long faced a scarcity of fresh greens for animal feed. A lack of adequate feed severely restricts livestock productivity, resulting in slow growth, limited weight gain, or even health issues. In dairy cattle farming, feed typically consists of 60% greens and 40% concentrates (Suhendra et al., 2015). This composition is similar to ruminant feed, which usually includes 70% green fodder and 30% concentrate (N Saking & N Qomariyah, 2017; Santoso et al., 2013) Moreover, feed expenses are a critical factor in determining production costs. Amam & Harsita (2019b) observed that production costs are closely linked to feed expenses. Furthermore, Sari et al., (2016) emphasized that the ruminant population in an area is directly related to the demand for feed, especially green fodder. This situation highlights the essential role of feed in livestock farming.

As noted by Santoso et al., (2013), dairy cattle farming encounters challenges such as limited land for growing green fodder and the high expense of feed. The availability of feed is determined by factors like daily temperature, climate, and groundwater supply, which significantly impact the year-round supply of green fodder (Ridwan & Widyastuti, 2001). To address these limitations, utilizing local resources such as agricultural and industrial waste for green fodder or concentrate, along with preserving green fodder and agricultural waste through methods like silage, ammonia treatment, and haymaking, are strategic measures to ensure consistent feed supply throughout the year (Magrianti et al., 2019;Pramono & Yuliawati, 2020). Indonesia possesses local resources suitable for feed. Besides the abundant green fodder in rural areas, agricultural by-products like palm oil waste, jabon, rice straw, and cocoa waste serve as viable feed sources.

The consistent supply of green fodder poses a significant challenge in community livestock systems, particularly in dairy cattle farming. Variations in green fodder availability, especially during dry periods, often limit livestock maintenance, leading to reduced productivity. Feed preservation methods like silage have been introduced as a strategic approach to address the seasonal imbalance in green fodder supply. As noted by Ohmomo et al., (2002), silage enables the use of nutritionally rich feed crops throughout the year, not just during the rainy season. Besides serving as a preservation method, silage can enhance the nutritional quality of feed by incorporating local materials such as rice straw, palm oil waste, cocoa leaves, and other agro-industrial by-products. Utilizing local feed materials through silage technology offers an economical, environmentally friendly, and sustainable feed alternative. However, despite being promoted through various dissemination and training programs, the adoption of silage among smallholder farmers remains low. Abdullah (2016) observed that the innovation of using fermented rice straw as feed is still primarily adopted by slow adopter groups, due to limited knowledge and interest in innovation.

While previous research has predominantly concentrated on the technical aspects and nutritional efficacy of silage, the socio-economic and behavioral dimensions of farmers' technology adoption have seldom been thoroughly explored. The success of adopting new technologies is significantly shaped by farmers' attributes, such as their knowledge, education, and motivation, as well as geographical factors, infrastructure support, and the effectiveness of dissemination strategies (Rogers, 2003;Irawan et al., 2015). Mardikanto (1988) highlighted the necessity of synergy between the nature of innovation, the recipients, and communication processes to foster successful adoption. Conversely, Bogor Regency, a key dairy cattle hub in West Java, holds substantial promise for silage development. In 2023, the dairy cattle population reached 6,099 (BPS, 2024), distributed across productive regions like Pamijahan, Cibungbulang, Ciawi, Cisarua, and Cijeruk. This potential is bolstered by the plentiful availability of green fodder during the rainy season and agricultural by-products like rice straw, given that the rice harvest area spans 50,013 ha with a production of 295,090 tons in 2024 (BPS, 2024b). However, no comprehensive study has yet linked these local resources' potential with the readiness and challenges of adopting silage technology at the dairy farmer level. Consequently, this study seeks to address the knowledge gap concerning the use of local feed through silage technology within the social, economic, and technical context of smallholder farmers in Bogor Regency. Specifically, the study aims to: 1) Identify the potential and challenges in utilizing local feed and the opportunities for implementing silage; 2) Examine the factors influencing the adoption of local feed innovations; 3) Develop strategies to enhance the capacity and sustainability of silage technology adoption among dairy farmers.

2. Research methods

2.1. Location and Time of Research

The study took place from January to December 2024. The research site was deliberately selected, specifically Cijeruk District in Bogor Regency, West Java Province. This location was chosen due to its potential for dairy cattle development, as outlined in the Minister of Agriculture's Decree No. 472 of 2018, and because of the availability of local resources for producing silage from animal feed. Additionally, the area offers promising opportunities for strong collaboration with partners, such as the Bogor Regency Fisheries and Animal Husbandry Service.

2.2. Analytical Approach and Framework

This study is an Action or Applied Research project aimed at designing the development of dairy cattle farming by leveraging local feed resources. The execution of this initiative involves three main strategies: (a) Agroecosystem (location-specific), which capitalizes on the distinctive natural resources and local socio-economic conditions to drive unique livestock enterprises; (b) Agribusiness system, which focuses on the development of integrated agribusiness systems and operations, examined through a series of interconnected activities; and (c) Participatory approach.

An analytical framework was developed, drawing on the innovation adoption theory (Rogers, 1994), the renewal concept by Lionberger and Gwin (Mardikanto, 1996), and various studies on livestock feed silage innovation and its implementation efforts (Figure 1). This framework serves as the foundation for this research. The ultimate goal of this initiative is to sustainably enhance the income and well-being of farmer and breeder families by boosting the capacity and productivity of dairy farmers using local resources.

The adoption of innovation (Y1) is believed to be affected by several factors or latent variables (X) and their respective indicators. These include four latent variables: the characteristics of farmers (X1), the nature of the innovation (X2), the role of the extension worker or companion (X3), and the external environment (X4). These factors not only impact the degree to which farmers adopt innovations but are also thought to affect the consequences of adoption (Y2). The framework further explains that each latent variable is constructed from indicators that represent it.

2.3. Types and Methods of Data Collection, and Sampling Methods

The data gathered includes both primary and secondary sources. Primary data was obtained through Focus Group Discussions (FGD) and detailed interviews using a structured questionnaire directed at dairy farmer respondents. Secondary data was sourced from the Department of Agriculture and Livestock, the Statistics Office, and online searches.

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The study's population in Bogor Regency consisted of all members of the Dairy Cattle Farming School (SPR) located in Tajurhalang Village, Cijeruk District, Bogor Regency. Within this SPR, there are two farmer groups engaged in dairy farming: the Kania group and the Mandiri Sejahtera Group. Together, these groups comprise a total of 47 dairy farmers, all of whom serve as research respondents.

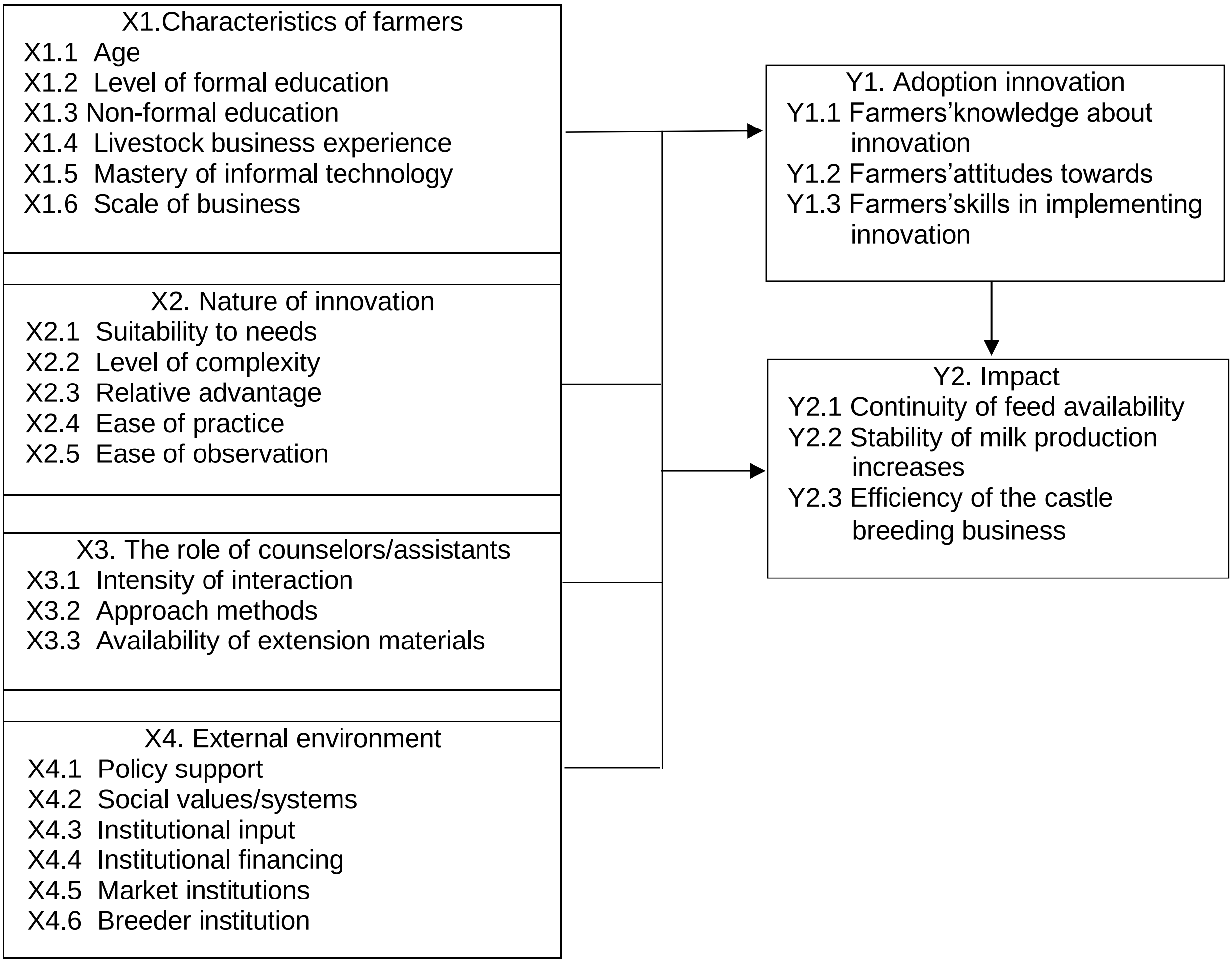

Figure 1. Research analysis framework for increasing the capacity and productivity of dairy cattle farmers based on local feed potential

2.4. Data Analysis Methods

Data analysis, besides description, also uses the Structural Equation Model (SEM) – Partial Least Squares (PLS) that aims to test the fit model of the analytical framework that has been created in this study. Partial Least Squares (PLS) is also used to determine the extent to which the independent variables (independent variable) can explain and describe the total diversity of dependent variables (dependent variable), and see the influence of independent variables on dependent variables. According to Solimun (2002), SEM is also a measurement technique based on empirical indicators. There are 3 models analyzed according to SEM rules, namely: (1) Factor analysis model, (2) Path analysis model, and (3) Regression analysis model.

The PLS-SEM analysis framework is composed of two sub-models: the measurement model, also known as the outer model, and the structural model, often referred to as the inner model. The measurement model illustrates how the manifest or observed variables represent the latent variables that need to be measured. In contrast, the structural model indicates the strength of the relationships between the latent variables or constructs. Typically, the PLS evaluation model involves assessing both the outer and inner models (Latan & Ghozali, 2012).

Confirmatory Factor Analysis (CFA) is the method employed to evaluate the model, specifically by examining the dimensionality of a construct. The assessment of the measurement model, also known as the outer model, is conducted to determine the model's validity and reliability. Reflective indicators in the outer model are assessed through convergent and discriminant validation of the indicators that form the latent construct, as well as composite reliability and Cronbach's alpha for the indicator block (Chin, 1998).

To evaluate the inner model, one can test the structural model both with and without mediation, considering R Square and goodness of fit. Analyzing the structural model without mediation helps determine the direct significance of the relationship between independent and dependent variables, excluding the influence of intervening variables. The strength of the correlation between these variables is reflected in the path coefficients table. A relationship is deemed significant at a 5% significance level if the T-statistics value exceeds 1.96. In this research model, the VAF (Variance Accounted For) value for partial mediation ranges from 0% to 100%. Higher values suggest partial mediation, with moderate partial mediation having a VAF value between 35% and strong partial mediation falling within the 55% range.

3. Results and Discussion

3.1. Characteristics of Location and Dairy Farmers

Tajur Halang Village is located in Cijeruk District of Bogor Regency, strategically positioned at the base of Mount Salak, with an elevation ranging from 600 to 870 meters above sea level. The terrain is characterized by hills and latosol soil, which varies in thickness from 130 to 500 mm, has a pH level between 4.5 and 6.5, a clay-like texture, and excellent water retention capabilities (BPS, 2024a). These environmental factors are highly conducive to agriculture and dairy farming due to the area's high humidity and relatively consistent rainfall throughout the year (Arsyad, 2010). Tajur Halang Village spans an area of 391 km^2, with 220 hectares dedicated to agriculture consisting of 5 ha rice paddy fields and 215 ha non-rice paddy fields that are ideal for dairy farming. The development of livestock potential in this village includes not only dairy cattle but also large ruminants such as beef cattle, small ruminants, and poultry.

Arsyad (2010) highlights that the primary influences on the growth of dairy cattle farming businesses are geographical conditions and soil fertility. Additionally, the support from the Cijeruk District's population, which reached 96,724 in 2024 (BPS, 2024a), further bolsters the presence of livestock farming in Tajur Halang Village. Many local residents actively participate in livestock farming groups, such as the Kania Group, established in 1982 by R. Subranta Jokopranata. The term "Kania" carries a philosophical significance, representing the Unity of Intention, Knowledge, and Charity, embodying the spirit of collaboration in managing livestock enterprises. Farmer groups like Kania play a crucial role in enhancing the productivity of dairy cattle farming. Firmansyah (2015) notes that these groups serve as platforms for farmers to exchange knowledge, technology, and resources. This aligns with the situation in Tajur Halang Village, where farmer groups have expanded into four distinct groups: Kania, Mandiri Sejahtera, Muda Berkarya, and Bina Mandiri.

The study involved 47 participants, all of whom were male farmers (100%), with 62% being over the age of 50 that is detailed in Table 1. A mere 4% of the respondents were in their early adulthood (20–30 years), while 34% fell into the middle-aged bracket (31–50 years). The farmers generally had a low level of formal education, with 74% having only completed elementary school (SD). Nevertheless, about 55% of them had participated in non-formal training related to dairy farming development. The predominance of older individuals in the dairy farming sector in Tajur

Halang Village suggests that this enterprise has been established for a considerable time, dating back to the founding of the Kania Group in 1982. However, the involvement of younger farmers (approximately 40%) signifies a generational shift in the livestock industry. Firmansyah (2015) emphasizes that the presence of young farmers is crucial for the sustainability of the livestock business, as they are more receptive to innovation and new technologies. Conversely, the level of cosmopolitanism among farmers in this village remains low, with 49% seldom traveling to the city center or hosting visitors from outside the village. This situation can restrict farmers' access to new information and technology. According to Rogers (2003), low cosmopolitanism can hinder the adoption of innovations within the farming community.

In Tajur Halang Village, dairy farming is conducted on a small scale. Typically, farmers own about five dairy cows and employ an intensive care system. They feed the cows twice daily with a diet of grass and concentrate. Artificial insemination (AI) is used for breeding, achieving a 66% pregnancy success rate after two AI attempts.

In Indonesia, smallholder livestock farming is characterized by small-scale operations and intensive maintenance systems. As noted by Soeparno (2012), this type of farming holds significant potential for development due to its relatively low operational costs and accessibility to rural populations. Nevertheless, livestock farmers encounter major challenges, such as the scarcity of green fodder during the dry season and the volatility of concentrate prices. The adoption of alternative feed remains minimal, with 96% of farmers having never utilized it, primarily due to a lack of knowledge and the complexity of producing alternative feed. Widiyanti et al., (2018) suggest that agricultural waste could serve as an alternative feed to lessen reliance on green fodder and concentrates. However, increased socialization and training are necessary to promote the adoption of this technology.

Table 1 Characteristics of respondents (dairy farmers) in Tajur Halang Village, 2023

Characteristics	Category	Amount	Percentage
Gender	Man	47	100
Age (years)	Teenagers (< 20 years)	0	0
	Early adulthood (20 – 30)	2	4,26
	Middle age (31 -50)	16	34,04
	Advanced age (>50)	29	61,70
formal education	No school	0	0
	SD	35	74,47
	Junior High School, Senior High School	8	17,02
	Academy, PT	4	8,51
non-formal education	Never	21	44,68
	1-2 training	18	38,30
	3 training	3	6,38
	More than 3 trainings	5	10,64
Business Experience	1-10 years	25	53,19
	11- 20 years	15	31,91
	21- 30 years old	4	8,51
	31-40 years	3	6,38
IT Access	Very low	6	12,77
	Low	7	14,89
	Currently	14	29,79
	High	20	42,55
Number of ownership Cattle	1-5 tails	33	70,21
	6-10 tails	6	12,77
	11-15 tails	6	12,77
	16-20 tails	2	4,55

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3.2. Potential and Problems of Utilizing Local Feed, and Implementation of Silage Development

The findings of the study indicate that Tajur Halang Village possesses local feed resources that can be enhanced to fulfill the feed requirements of dairy cattle in the region. In Cijeruk District, farmers commonly cultivate and use various types of green fodder, including elephant grass, odot, and legumes. Agricultural by-products such as rice straw and corn straw are already being utilized. However, waste from secondary crops and vegetables remains largely untapped. This situation aligns with the research by Magrianti et al., (2019), which found that dairy cattle feed predominantly used by farmers includes elephant grass, field grass, rice straw, and corn straw. The classification of feed used by dairy farmers in Tajur Halang is detailed in Table 2. This classification is based on the feed material classification provided by the National Research Council (NRC) (Utomo et al., 2020).

Through proximate and productivity assessments, it is confirmed that livestock feed can include pakchong grass and biovitas grass due to their superior productivity compared to other forage grass. Additionally, rice bran and cassava serve as viable energy sources. Among agricultural residues, corn stalks stand out as a promising option for dairy cattle feed, given their substantial nutritional value and digestibility. Corn stalks encompass the entire plant, including stems, leaves, and young fruit, typically harvested when the plant is 45-65 days old, as noted by Soeharsono & Sudaryanto (2006). Indigofera legumes, despite having lower productivity than grasses, can be used as a natural protein source from greens because they contain relatively high crude protein levels.

Table 2 Classification of dairy cattle feed in Tajur Halang

Feed Classification	Type
Pasture and fresh green fodder (class 2)	Setaria grass, field grass, biogen grass, odot grass, elephant grass, pakchong grass
Dry forage and straw (class 1)	Corn cobs and rice straw
Energy sources (grade 4)	Concentrate, cassava and rice bran
Protein sources (class 5)	Tofu dregs

In Tajur Halang Village, local sources for complementary feed ingredients like molasses, probiotics, minerals, and vitamins are unavailable. However, these can be sourced by partnering with local feed material suppliers in the Bogor region. The dairy cattle group maintains a regular supply of concentrate from a feed distributor who also offers raw materials and animal feed supplements. Additionally, Bogor Agricultural Development Polytechnic can supply the necessary probiotics. Regular quality testing is essential for the concentrate and feed materials to ensure the raw materials meet quality standards.

Farmers encounter several challenges concerning animal feed: 1) Although green fodder is accessible during the dry season, it incurs higher costs compared to the rainy season, and 2) the price of concentrate is unstable; when raw material costs rise, producers lower concentrate quality, leading to reduced milk production. Farmers note that green fodder is plentiful during the rainy season in their region. In contrast, during the dry season, its availability diminishes, yet they manage to fulfill the green fodder requirements for their dairy cattle. To do so, they venture further afield, often into forests, mountains, or undeveloped residential areas, to find grass. Despite the increased distance and expenses, farmers believe they can still meet their livestock's green fodder needs. However, they find it increasingly challenging to obtain green fodder due to expanding tourism developments, which limit available land, even as demand remains high.

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The study's findings indicated that farmers faced challenges in securing feed supplies. For instance, the availability of tofu dregs and rice bran is limited, and competition with other farms further complicates consistent access. Rice straw can serve as an alternative feed source, but it requires treatments like ammonization and/or fermentation to enhance its nutritional value and digestibility (Amin et al., 2019; Suningsih & Ibrahim, 2018). This is necessary because rice straw's use as animal feed is hindered by its low nutritional quality, characterized by minimal crude protein and high crude fiber content (Weimer et al., 2003), along with significant lignin and silicate levels, which reduce its digestibility. The combined effects of lignification and silicification contribute to the poor digestibility of rice straw (Van Houtert, 1981).

Among the participants, some are dairy farmers affiliated with SPR, and their experience in managing SPR and raising dairy cattle indicates that cultivating green fodder and producing silage is familiar to them. However, they have not yet adopted the technology sustainably and comprehensively. Additionally, some farmers lack experience in dairy farming. They have a basic awareness of silage technology but do not fully grasp it. This training aims to enhance the participants' knowledge, attitudes, and skills, enabling them to effectively adopt green fodder cultivation and silage technology.

The proficiency levels of individuals involved in animal feed management differ, encompassing low, medium, and high categories. The skills assessed include cultivating green fodder and producing silage, which involves preparing components, chopping grass, mixing, and storing it in barrels and plastic. Over half of the training attendees possess medium to high proficiency. Enhanced skill levels contribute to greater business effectiveness and efficiency. This aligns with Padmowihardjo (2000) assertion that farmer skills involve imparting knowledge to transform farmer behavior, making it more effective, efficient, and swift through technological advancements.

3.3. Factors Influencing the Adoption of Locally Made Feed Innovations

To analyze the factors influencing the adoption of silage innovation, SEM PLS was employed. The data was processed using a repeated indicator second-order model approach in SEM PLS. All indicators from the first-level construct were reused as indicators for the second-level construct. In the first stage, the measurement model was evaluated by assessing the loading factor (LF). Variables with LF values below 0.70 were excluded from the model, as they did not meet the minimum standard required to reflect the intended construct. To ensure construct validity in the measurement model, each item's LF value was evaluated. According to the recommended criteria, items with an LF less than 0.70 should be removed, as they fail to meet the minimum standard for reflecting the intended construct. Consequently, several items with LF < 0.70 were removed to enhance measurement quality. This process aims to improve the accuracy of measuring the intended variables and ensure that the remaining items better represent the construct. The external environmental variable (X4) had an LF of less than 0.7 and was thus removed from the model. Subsequently, stage 2 model testing was conducted using variables that met the stage 1 requirements.

In the second stage, the structural model is assessed by examining the t-value and p-value concerning the variables. For hypothesis testing with statistical values, a 5% error rate requires a T-statistic value of 1.96. Thus, the hypothesis is accepted if the t-statistic exceeds 1.96. Similarly, for acceptance based on p-values, the hypothesis is accepted if the p-values are less than 0.05. The outcomes of these tests are presented in Table 3.

Table 3 Structural model testing/hypothesis testing

Variables	T-Statistic	P-Value
Innovation Adoption -> Impact	2.663	0.008
Farmer Characteristics -> Adoption of Innovation	2.398	0.017
Role of Extension Workers -> Adoption of Innovation	2.002	0.045
Nature of Innovation -> Adoption of Innovation	4.003	0.000

Table 3 presents the outcomes of the statistical model analysis, indicating that the extent to which silage technology is adopted is affected by factors such as farmer characteristics, the involvement of extension workers, and the nature of the innovation. The adoption of this innovation impacts the effects of silage adoption. Figure 2 illustrates the results of the structural model test.

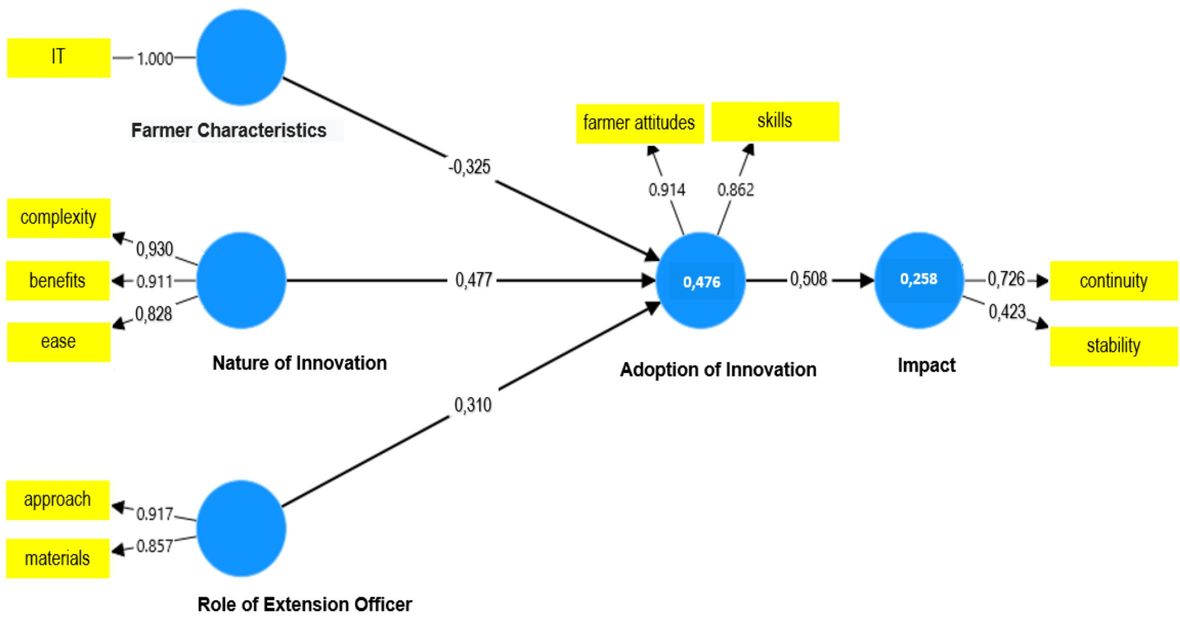

Figure 2 Structural model test results

To ensure model suitability, it can be seen from the value R-Square in Table 4.

Table 4. Values R-Square and R-Square adjusted

	R-square	R-square adjusted
Adoption of innovation	0.476	0.433
Impact	0.258	0.239

The findings underscore the significance of farmer characteristics, the influence of extension workers, and the type of innovation in shaping the extent of innovation adoption, which subsequently has a direct impact on the outcomes. The structural model test results reveal that innovation adoption has a substantial effect on the outcomes, with a relationship coefficient of 0.508 ($p = 0.008$). This suggests that a higher level of innovation adoption leads to a more pronounced positive impact.

There is a significant negative correlation between farmer characteristics and the adoption of innovation, with a coefficient of -0.325 (p = 0.017). This suggests that certain farmer traits that do not favor innovation can impede the adoption of new practices. The variable used to represent farmer characteristics is proficiency in information technology. The findings suggest that even strong information technology skills do not promote the adoption of silage technology among farmers. These results contrast with the study by Baba et al., (2021), which found that a farmer's age influences the adoption of agricultural waste utilization. On the other hand, Abdullah (2016) contends that the slow adoption rate is due to a lack of interest in technological innovation, stemming from insufficient knowledge about feed technology innovations and poor communication about these innovations, leading to farmers' fear of failure and risk-taking.

The influence of extension workers plays a crucial and positive role in the adoption of innovations, as indicated by a correlation coefficient of 0.310 (p = 0.045). This suggests that proactive and efficient extension workers can motivate farmers to embrace new innovations. This observation aligns with the research by Baba et al., (2021), which highlighted that interaction with extension workers affects the adoption of agricultural waste as feed for dairy cattle. Similarly, Hertanto et al., (2018) emphasized that implementing silage technology among livestock farmers necessitates a mentoring program for both individual farmers and livestock groups. This program involves guidance in managing silage product businesses and distributing them to both members and external markets. In relation to the mentoring role in dairy cattle feed, Magrianti et al., (2019) suggest expediting the enhancement of the quality, content, and methods of extension regarding green fodder.

Moreover, the characteristics of innovation have a notably strong positive correlation with the adoption of innovation, as indicated by a coefficient of 0.477 (p = 0.000). This suggests that the more farmers perceive an innovation as engaging, pertinent, and beneficial, the higher the likelihood of its adoption. Consequently, farmers must acquire extensive information about silage innovation to thoroughly comprehend its nature. This situation aligns with Abdullah's (2016) findings, which assert that the innovation process heavily relies on farmers' understanding of the innovation and effective communication of the innovation to them. Intiaz et al., (2022) also highlighted a significant link between the nature of innovation and the degree of adoption by farmers.

The study's findings indicate that the model's innovation characteristics encompass factors such as meeting needs, complexity level, relative benefit, ease of implementation, and observability. The process of deciding to adopt a technology involves several stages, including awareness, interest, evaluation, trial, and ultimately, the decision to embrace the innovation (Heryanto et al., 2016). Fatchiya et al., (2016) noted that when the outcomes of an innovation are easily visible to others, they can be readily communicated and boost the adoption process. Furthermore, the adoption of agricultural technology by farmers is influenced by their demand for the technology and its compatibility with the local environment (Burhanuddin et al., 2019).

3.4. Sustainability Strategy for Adoption and Capacity Building of Dairy Farmers

Dairy farming in Tajur Halang Village, located in Cijeruk District of Bogor Regency, holds significant potential to evolve into a key milk production hub in the area. However, challenges such as restricted access to high-quality feed, minimal use of modern technology, and the complex institutional dynamics among farmers hinder efforts to boost productivity and improve farmers' welfare. Consequently, adopting sustainable technology and enhancing farmers' capabilities are crucial strategies to ensure the long-term viability of dairy farming enterprises. Analyzing the factors that affect innovation adoption reveals two essential strategies: (1)

Enhancing productivity through technological advancements, and (2) Strengthening farmers' capacities via institutional innovations

3.4.1. Increasing productivity through technological innovation

Concept of Crop-Livestock Integration System (SITT)

One significant technological advancement aimed at boosting dairy farmers' productivity is the Crop-Livestock Integration System (SITT). This system merges diversification and intensification in managing both crop and livestock farming operations. It aligns with the circular principle, where the waste from one element serves as input for another. For instance, plant residues like rice straw and vegetable waste can be converted into animal feed, while cow manure can be transformed into organic fertilizer for crops, thus decreasing reliance on chemical fertilizers.

The potential for implementing SITT in Cijeruk District is significant, thanks to the supportive agroecosystem characteristics. To facilitate the adoption of this technology, training and technical support from agricultural extension workers and universities are crucial.

Technology Alternatives for Productivity Enhancement

Some technological options that are pertinent to dairy farmers include: Intensive housing technology, which enhances cow comfort and aids in feed management; Compost processing technology, which transforms cow manure into organic fertilizer for plants; and Rice straw fermentation technology, which creates a more nutritious alternative feed. Despite the availability of these technologies, their adoption among farmers remains low. Consequently, ongoing socialization and informal training are necessary.

3.4.2. Increasing the capacity of livestock farmers through institutional innovation

Strengthening of Livestock Institutions and Mentoring/Extension

Institutions focused on livestock, like the People's Livestock School (SPR), are crucial in enhancing the skills of livestock farmers. In the Cijeruk District, the SPR, initiated by LPPM IPB, serves as a foundation for the development of livestock farmer organizations. The SPR's organizational framework comprises a manager, secretary, treasurer, and various sections responsible for task allocation that is shown in Figure 3. The success of SPR hinges on group dynamics, transparency, and active member involvement. As noted by Firmansyah (2015), robust institutions can boost the efficiency and effectiveness of programs aimed at building the capacity of livestock farmers. Consequently, it is essential to strengthen these institutions through mentoring and training.

Collaboration with Partners and Research Institutions

To support the sustainability of technology adoption, collaboration with partners such as universities, research institutions, and the private sector is essential. The role of each institution in the livestock institutional network includes:

a. BRIN and BSIP: Providing technological innovation and institutional advocacy.
b. Local Government Office: Providing market and capital information.
c. Universities and NGOs: Providing business and financial management consulting.

This partnership not only enhances farmers' abilities but also guarantees the successful application of technological advancements. As noted by Arsyad (2010), collaboration between organizations can speed up the adoption of innovations among farmers.

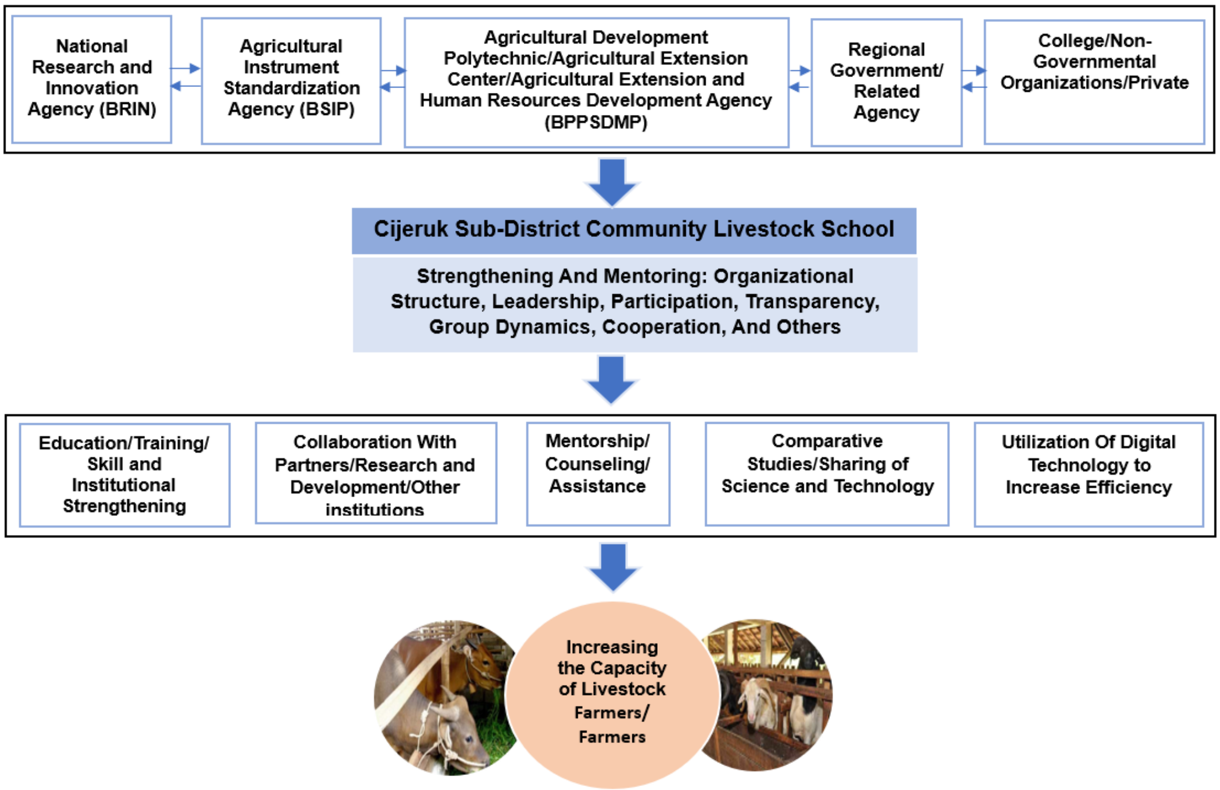

Figure 3 Framework of the model for increasing the capacity and productivity of livestock farmers in the Cijeruk District through existing institutions.

3.4.3. Steps to increase the capacity and productivity of livestock farmers

To effectively enhance the capacity and productivity of livestock farmers sustainably, it is imperative to develop a comprehensive roadmap that encompasses the following strategic steps:

a. Provision of quality green fodder: Planting fodder crops such as lamtoro, alfafa, and indigofera on fallow land.
b. Utilization of agricultural waste: Processing plant waste into animal feed.
c. Partnership with Farmers/Farmers Groups/Farmers Associations: Forming a cooperation to provide quality feed.
d. Strengthening SPR institutions: Ensuring transparency and group dynamics.
e. Innovation assistance: Involving related institutions to assist farmers.

Implementing this strategy typically requires two to three years to yield significant results. To ensure the program's long-term sustainability, it is crucial to establish clear achievement indicators at every phase.

4. Conclusions

Tajur Halang Village holds significant promise for expanding dairy farming enterprises. Nonetheless, obstacles such as restricted access to information, low levels of cosmopolitanism, and reliance on green fodder must be addressed through training, awareness programs, and the adoption of modern technology. With backing from the government and academic institutions, this village could emerge as a key milk production hub in Bogor Regency. The factors influencing the uptake of silage innovation include farmer characteristics, the influence of extension workers, and the inherent qualities of the innovation itself, all of which are crucial in determining the extent of innovation adoption. Farmers' adoption of innovation directly impacts outcomes, evidenced by consistent feed availability, stable increases in milk production, and improved efficiency in dairy farming operations. A strategy for sustainable technology adoption and enhancing the capabilities of dairy farmers in Tajur Halang Village can be realized through a blend of technological and institutional innovations. The successful implementation of SITT, strengthening of SPR institutions, and partnerships with strategic allies are essential. However, the effectiveness of this strategy hinges on the commitment of all stakeholders, including farmers, the government, and universities.

To ensure the continued use of silage technology in dairy farming, the government should create policies focused on enhancing farmers' capabilities and bolstering institutional frameworks. Key actions include offering incentives to farmers who implement silage technology, enhancing the role of agricultural extension workers in education and guidance, and fostering partnerships among the government, universities, and the private sector. These measures can boost the competitiveness of dairy farming in Tajur Halang Village. Furthermore, regulations that provide broader access to resources, such as funding and technology, can speed up the adoption process and minimize obstacles to innovation at the farmer level.

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