



Struggling farmers, weak cattle, rising imports: NutriFarm as a solution to reduce import and support the realization of free nutritious meals program

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ABSTRACT

Background: Indonesia continues to face inefficiencies in ration formulation among smallholder livestock farmers, resulting in low productivity and sustained dependence on imported meat and milk. This study aims to design NutriFarm, a digital livestock-assistance application intended to improve feed efficiency and strengthen national food security. Previous studies emphasize that precise nutrition management, optimized use of local feed resources, and the adoption of digital systems such as smart farming and precision livestock farming can significantly enhance livestock performance and reduce production costs. **Methods:** This study employed a qualitative approach through observation, systematic literature review, and descriptive analysis to identify challenges in feed management, technological adoption, and digital innovation opportunities. A Design-Based Research framework was used to develop key application features, formulate the implementation model, and construct a pentahelix-based collaborative ecosystem for farmer assistance. **Findings:** The results indicate that NutriFarm has the potential to improve the accuracy of ration formulation, maximize the use of local feed resources, and strengthen farmers' capacity in nutritional monitoring and management practices. Integrated features—including automated ration calculation, nutrient evaluation, plant identification, and daily feed logging—enhance data-driven decision making. These findings align with theories of livestock nutrition and precision livestock farming, which highlight the importance of balanced nutrient supply, continuous monitoring, and resource optimization. **Conclusion:** NutriFarm can serve as a strategic tool to improve the productivity of smallholder livestock systems and reduce reliance on imported animal products, thereby supporting the national nutritious-meal program. **Novelty/Originality of this article:** This study offers an integrated design that combines precise nutrition management, local feed optimization, automated plant identification, community-based assistance, and a multi-stakeholder pentahelix ecosystem within a single digital innovation model, representing a comprehensive approach not yet developed in Indonesia's smallholder livestock

KEYWORDS: NutriFarm; feed formulation; precision livestock farming; digital agriculture; food security.

1. Introduction

The livestock sector has a strategic role in the national food system because it is the main provider of animal proteins, such as meat and milk, which have an important role in fulfilling community nutrition. The availability of stable, affordable, and quality sources of

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animal protein can be said to be one of the indicators of a country's food security. However, until now, Indonesia still faces serious challenges in meeting national meat and milk needs. Dependence on imports is still high because domestic production has not been able to keep up with the increasing level of demand. Although beef production has increased, the amount is still insufficient for domestic needs (Fig. 1).

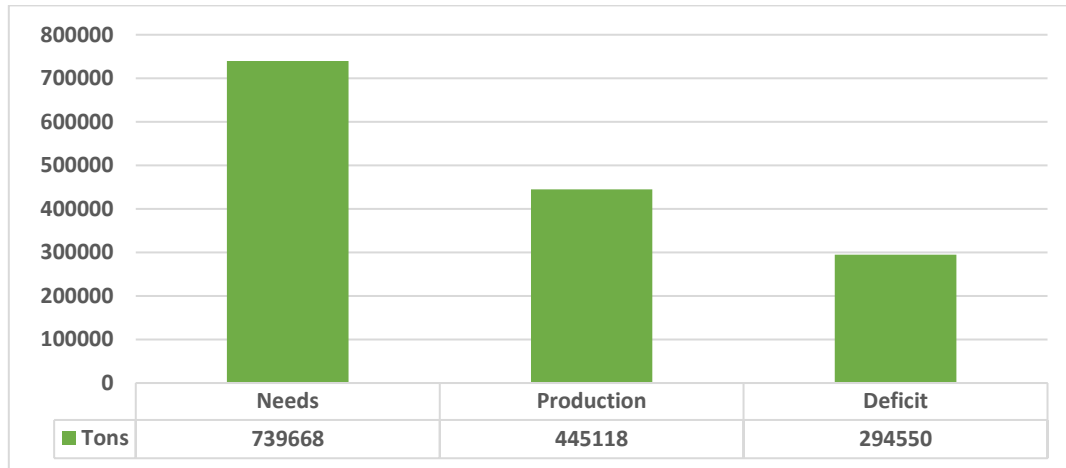


Fig. 1. National meat needs, production, and deficit in 2025

The Ministry of Agriculture estimates that national meat needs in 2025 will reach 739,668 tons, while it is predicted that in 2025 Indonesia will only be able to produce 445,118 tons, so that Indonesia will experience a meat deficit of 294,550 tons. This imbalance will continue if no solution is offered, so imports become the government's main solution in covering the supply shortage. The same thing happens in the dairy sector, where domestic production only accounts for around 22.7% of the total needs, while the rest is met by imports that continue to increase every year (Ginting et al., 2023). This indicates that Indonesia's animal food security is still in a vulnerable position, especially to global geopolitical dynamics, international price fluctuations, and trade barriers.

One of the main causes of dependence on imports is the low efficiency in the preparation of animal feed rations. Feed is the largest component in the production cost of livestock business, which reaches 60-80% of the total cost, so the efficiency of ration preparation is a key factor in increasing the competitiveness of livestock businesses. However, most smallholder farmers still rely on conventional feed preparation patterns, which are based on hereditary habits and experiences, not based on the calculation of the specific nutritional needs of each livestock.

Imoptimal feed preparation has a direct impact on the growth and productivity of livestock, causing smallholder farmers to have difficulty increasing their production. In addition, the abundant availability of local feed ingredients, such as agroindustrial waste, agricultural by-products, and local forage, has not been optimally utilized due to limited technical knowledge regarding nutritional characteristics and processing methods. In fact, around 78% of beef production in Indonesia depends on smallholder farming (Zakiah et al, 2017). In addition, fluctuations in feed prices and limited access to quality resources have worsened the condition of local farmers (Ministry of Agriculture, 2023).

On the other hand, the government's free nutritious meals program has the potential to increase demand for meat and milk. However, dependence on imports threatens supply and price stability in the global market. If this problem is not addressed immediately, the sustainability of the program can be threatened due to fluctuations in food prices. Therefore, solutions are needed that can help farmers manage feed more optimally to increase the productivity and independence of the livestock industry in Indonesia.

Digitalization and innovation in the livestock sector are the main solutions in improving production efficiency and the competitiveness of local farmers. In line with the

development of digital technology, various industrial sectors have transformed towards data-based and automation systems, including the agriculture and livestock sectors. The concept of Precision Livestock Farming (PLF) and smart farming has begun to be introduced as a modern approach to improving the efficiency, health, and welfare of livestock through the use of technologies such as the Internet of Things (IoT), artificial intelligence (AI), and algorithm-based data analysis. However, the implementation of the concept in Indonesia still faces structural barriers, mainly due to the segmentation of farmers dominated by family-based smallholder farmers (smallholder farmers), who often have limited access to technology, capital, and advanced technical training.

With limited knowledge, smallholder farmers demand innovation in the animal feed formulation system. For example, the use of Internet of Things (IoT)-based applications allows farmers to monitor the condition of livestock in real-time and prevent diseases early. To answer this challenge, there is NutriFarm, a digital application designed as a smart solution in compiling optimal animal feed rations. NutriFarm not only helps farmers determine the appropriate feed composition, but also provides access to nutritional information, feed processing methods, and the use of local feed ingredients available around them. With this application, it is hoped that livestock productivity can increase, dependence on meat and milk imports will be reduced, and support the sustainability of the free nutritious meal program launched by the government.

Furthermore, the existence of NutriFarm has a strong relevance in supporting national policies such as the free nutritious meals program launched by the government. This program aims to improve the quality of human resources through increasing access to animal protein. However, the sustainability of this program will depend heavily on the independence of domestic livestock production. Without increased productivity based on feed efficiency and livestock management, dependence on imports could be a threat to the sustainability of the program.

The increase in the need for national animal protein requires an efficient, stable, and sustainable livestock production system. Protein is very important for human growth and health, referring to the role and function of protein, lack of protein consumption can have various fatal consequences. Based on the results of the study, the average daily protein consumption of the Indonesian population per capita in 2020 was 61.98 grams. Of the total, the main sources of animal protein are divided, of which 8.43 grams come from marine products (such as fish, shrimp, squid, and shellfish), 4.05 grams come from meat, and 3.47 grams come from eggs and milk (Santoso, 2022). Overall, the average consumption of animal protein sourced from livestock reached 7.52 grams per capita per day. Increasing the consumption of animal protein from livestock is urgent. Efforts to achieve this improvement must be carried out through two main channels, namely increasing nutrition awareness and community income, and improving the efficiency of businesses run by the community. The responsibility to intensify the increase in animal protein consumption is not only borne by the government, but also by all members of society. Various studies show that developing countries face major challenges in maintaining animal food sufficiency due to limited productivity of people's livestock. This condition is also experienced by Indonesia, where most meat production depends on small-scale farmers so that increased production is highly dependent on the efficiency of feed management and livestock health. If nutritional aspects are not managed optimally, livestock productivity will remain low even though livestock populations are increasing.

The strategy to increase food security and the quality of Human Resources (HR) fundamentally depends on increasing the consumption of animal protein, in line with the livestock production potential of the region. This increase demands the availability of livestock food as a source of protein, as well as improving household access to this food through increasing income and expanding employment opportunities in rural areas (Rachman & Supriyati, 2011). However, increasing the availability of food from livestock products will not be optimal without focusing on the performance of the livestock itself. The availability of quality feed is a major determining factor in the performance of ruminant livestock. Recent studies confirm that balanced nutrition can improve conversion efficiency,

improve body weight gain, and reduce production costs. Unfortunately, the increase in production, food availability, and household income (as can be realized through agricultural technological innovations as advocated by Rachman & Supriyati (2011) is still hampered by the reality that smallholder farmers rely heavily on conventional feed without considering the specific nutritional needs of livestock. This knowledge gap causes feed inefficiency which has a direct impact on productivity and leads to Indonesia's dependence on meat and milk imports to meet domestic demand.

Indonesia's food security is highly dependent on the availability of beef as the main source of animal protein. Increasing population, urbanization, and increasing income encourage beef consumption to continue to rise from year to year. Beef consumption reported by the Central Statistics Agency/*Badan Pusat Statistik* (BPS) also continues to move up, so that the projected national demand reaches millions of tons every year. However, domestic production has not been able to catch up with this consumption growth, so imports of live cattle and frozen meat from other countries are still the main support for national needs among countries that Indonesia is dependent on imports, namely Brazil, Australia, and India (Maharani et al., 2024). This dependence is a challenge to realize food security, especially meat and the independence of animal protein supply. On the other hand, domestic beef cattle production capacity is not enough to keep up with the surge in consumption.

As a consequence of these conditions, efforts to increase national beef cattle production require a more comprehensive understanding of the factors that affect the performance of the livestock subsector. Challenges not only arise in the production aspect, but also in the industrial structure which is still dominated by small-scale farmers with limited capital, technology, and market access. Uneven distribution of livestock between regions, fluctuations in feed prices, and supply chain inconsistencies also form the complexity of the problems faced.

The number of farmers and the price of beef are the factors that most affect the production level (Heatubun & Matatula, 2023). Their simulations show that rising prices and increasing the number of farmers can boost domestic production, although this is only effective when accompanied by improvements in feed supply systems, maintenance management, and supporting infrastructure. This shows that economic incentives and market mechanisms are still the main drivers for the increase in domestic production.

The increasing demand for national beef not only demands an increase in production volumes but also confirms the importance of understanding the structural dynamics in the livestock sector. The gap between demand and production indicates that the problem lies not solely in the number of livestock populations, but also in the ability of the cultivation system to respond to market changes. In this context, various factors such as the efficiency of farmers' businesses, the availability of capital, access to technology, and the stability of beef prices play a major role in determining the level of production. Small changes in these variables can influence the decision of farmers to expand their business, increase the number of livestock, or even stop business development. Therefore, the increase in beef cattle production needs to be understood as the result of the interaction between biological, technical, and economic aspects that are interrelated.

Access to quality feed is the most common obstacle in beef cattle development, because the increase in the number of farmers does not automatically result in better productivity if it is not accompanied by improvements in feed aspects, maintenance management, and other supporting infrastructure. The combination of forage feed and concentrate is able to produce more optimal daily body weight gain in several types of local cattle in several regions (Umaira et al., 2024). Feed quality has a direct effect on the growth, health, and efficiency of the livestock business. However, the availability of forage is often disrupted in the dry season, so the fattening process slows down and increases production costs. Therefore, the growth of the cow slows down, and the fattening period becomes longer.

Digital transformation in the agriculture and livestock sector is one of the strategies that has proven effective in increasing productivity. The concepts of smart farming and precision livestock farming utilize sensors, data analytics, and artificial intelligence to help

farmers make information-based decisions. This technology has been proven to improve efficiency in feeding efficiency, monitor livestock health in real time, and minimize the risk of disease. However, the implementation of this technology in Indonesia is hampered by limited access, costs, and lack of assistance to smallholder farmers.

In the last five years, mobile-based applications have become one of the easiest innovations for farmers and ranchers to adopt due to their practicality, inexpensive, and can be used without complex training. The government has been late in actively encouraging digitalization initiatives in various economic sectors to achieve this goal, so several programs, policies, action plans, and visions have been implemented since 2013 (Azis & Suryana, 2023). Research states that digital applications can improve farmers' ability in business management, production input efficiency, as well as access to important information such as market prices, weather, and technical recommendations. Thus, application-based digitalization such as NutriFarm has a great opportunity to be adopted by smallholder farmers in Indonesia as a tool for feed preparation and maintenance management.

The presence of food and livestock applications can have an impact on improving the accuracy of feed formulation and reducing farmers' operational costs. When nutritional information, feed composition, and livestock needs are available in one digital platform, farmers can make more precise decisions. By combining nutrition recommendations, feed crop identification, and feed processing education, NutriFarm can be a strategic instrument to strengthen the competitiveness of smallholder farms, while reducing Indonesia's dependence on animal protein imports.

2. Methods

2.1 Research design and approach

This research is qualitative research with observational data collection methods and collecting secondary data literature to prepare a design for the NutriFarm application as a solution to improve the efficiency of feed formulation in smallholder farms. The results of qualitative data are descriptive in the form of spoken or written words obtained from observations of the subject's behavior (Wijayanti & Fitriani, 2023). Observation is defined as a systematic method of collecting data by observing and recording the symptoms that are the focus of the research (Wijayanti & Fitriani, 2023). Supported by various scientific publications that provide an overview of livestock nutrition, feed, and livestock digitalization opportunities.

2.2 Data sources and collection process

Data collection is carried out through systematic searches of scientific journals, official government reports such as Central Statistics Agency/*Badan Pusat Statistik* (BPS) and the Ministry of Agriculture, publication of Satudata Pertanian, reference books on livestock nutrition, and policy documents related to food security. Secondary data is a source of data that indirectly provides data to collectors obtained from reference books, research journals, the internet, and others (Beno et al., 2022). The secondary data collection process was carried out from August to October 2025, focusing on literature relevant to livestock nutrition, feed formulation, precision livestock technology, agricultural digitalization, and the dynamics of meat and dairy imports. All sources are screened based on scientific credibility, year of publication, and suitability for analysis and application design needs.

2.3 Data analysis techniques

The data that has been collected is then analyzed through the process of condensation, presentation, and drawing conclusions to identify patterns, key problems, and innovation opportunities. Descriptive analysis is a technique for analyzing data by describing or

describing the data that has been collected (Arvyanda et al., 2023). Data analysis uses a method of depicting data without the intention of making general conclusions (Sutisna, 2020). Descriptive analysis was used to map the productivity gap of people's livestock, feed challenges, and the urgency of the presence of supporting technology. The results of the analysis became the basis for the preparation of scientific arguments regarding the role of NutriFarm in strengthening national food security.

2.4 Documentation, literature grouping, and design framework

The data collection technique was carried out by searching journal articles through secondary data and grouping the literature into the themes of feed, precision technology, livestock digitalization, and food security. The researcher searches and analyzes documents relevant to the research topic using the documentation method (Sulung & Muspawi, 2024). The design of the NutriFarm application follows the principles of Design Based Research (DBR) which is widely used in the development of digital innovations. This study uses Design Based Research with a qualitative approach to producing learning products, the products produced in the research can be used to support learning activities in accordance with field conditions (Zulkarnain et al., 2023). Design Based Research uses a design approach that includes key components such as research ethnography, formulation of research problems, use of references as reference sources, and procedural application of theory to generalize findings into specific contexts. Operationally, the research process involves a series of important stages, namely an evaluation system, collective data collection, documentation, and analysis (Mukarromah, 2020). The methodological equation used in this study is the use of the six-process theory developed by Hartung et al. (2021). The application design method includes problem identification based on the literature, conceptual analysis of user needs, formulation of core features (NutriMix, NutriCheck, FeedCam, Feed Techno, FeedLog, NutriTalk), and the preparation of an implementation ecosystem based on pentahelix collaboration. The final stage is in the form of mapping the government's corporate social responsibility hybrid funding model and hybrid funding scheme to ensure that NutriFarm can be widely adopted and sustainable.

3. Results and Discussion

3.1 Condition of livestock in Indonesia

The relationship between quality feed and increased meat and milk production is undeniable, with more optimal feed formulation, livestock can grow healthier and more productive, thereby increasing the supply of domestic animal protein. This is in line with the basic principle of livestock nutrition which states that the availability of energy, protein, minerals, and vitamins in the right ratio directly determines the performance of livestock production (Tillman et al., 2019). When feed is prepared precisely according to the biological needs of livestock, the efficiency of nutrient use increases and the impact can be seen in the increase in average daily body weight (ADG) and a more consistent increase in milk production (Orquera et al., 2023).

One of the biggest obstacles for farmers is the high cost of feed and dependence on imported raw materials such as soybean meal and corn, further worsening the condition of livestock in Indonesia. According to data from the Center for Agricultural Data and Information Systems in 2023, corn starch imports will reach 86.97% (USD 47.49 million) of Indonesia's total processed corn imports. Solid meal was 3.68% (USD 2.0 million).

Fluctuations in global commodity prices make farmers' production costs even higher, making the selling price of meat and milk less competitive compared to imported products. Meanwhile, the availability of local feed ingredients is often not utilized to the fullest. In addition, the lack of understanding of balanced feed formulation causes many farmers to provide feed originally, without considering the nutritional content needed by livestock. As a result, livestock growth is not optimal, milk productivity is low, and cost efficiency is poor.

Livestock productivity is influenced by environmental factors up to 70% and genetic factors are only about 30%. Among these environmental factors, the feed aspect has the greatest influence around 60%.

This shows that although the genetic potential of livestock is high, if feed does not meet the requirements of quantity and quality, high production will not be achieved. In addition to its great influence on livestock productivity, the feed factor is also the largest production cost in the livestock business. The cost of this feed can reach 60-80% of the total production cost (Sriwahyuni et al, 2025).

The productivity of local cattle in Indonesia is still relatively low, reflected in suboptimal body weight growth and declining feed quality, because farmers still rely on natural feed such as agricultural waste that is not nutritious (Lubis et al., 2024). In addition, small-scale farmers face serious obstacles in the form of limited access to modern technology and feed management training (Sihombing, 2021). The high burden of feed costs—with commercial feed accounting for about 60-70% of the total production cost—further aggravates the challenges for smallholder farmers to maintain the nutritional quality of livestock (Kuswoyo, 2025). These conditions also encourage Indonesia's dependence on food imports such as corn and soybeans for feed, as well as high imports of meat and milk—enough to alarm the need for innovation.

3.2 Impact of implementation on food security and food independence

The implementation of NutriFarm will directly support the free nutritious meal program, where the government targets increasing public access to quality protein sources at more affordable prices. With a more stable supply of meat and milk, this program can run more effectively and sustainably. The long-term impacts of the adoption of this application include the independence of farmers in managing feed and livestock production, the reduction of meat and dairy imports, and the improvement of people's welfare through better access to nutritious food. If widely implemented, NutriFarm can be a new milestone in the modernization of Indonesian livestock towards stronger and more sustainable food security. When feed formulation knowledge is no longer limited knowledge belongs to academics and nutrition consultants, but can be accessed directly by farmers through applications. Farmers who previously only followed traditional maintenance patterns will have a more scientific basis for decision-making. In addition, the ability of farmers to utilize local feed ingredients will also increase. The use of local feeds such as agroindustrial waste and quality forage can reduce dependence on imported feed ingredients such as soybean and corn meal, so that production costs can be reduced. This certainly has an impact on the economic stability of farmers and the competitiveness of domestic livestock products.

3.3 Solution ever offered

The government has made various efforts to increase the productivity of domestic livestock, one of which is through feed subsidies and training programs for farmers. However, the effectiveness of this policy is still limited because farmers need further assistance from experts. In addition, the application of technology in the people's livestock system is still relatively low, so innovations in the preparation of feed rations have not been widely integrated.

Several livestock productivity improvement programs that have been implemented, such as dairy and beef cattle assistance to farmers, have also not had a significant impact on reducing import dependence. One of the main factors for the failure of these programs is the lack of assistance in feed management and livestock health and the high cost of nutrition-related consultations for livestock.

According to Saputra & Widianita, (2023) There are also several examples of applications applied by farmers in Koto Baru district to meet basic needs while strengthening the economic capacity of farmers' households. Welfare in this context includes not only the ability to meet basic needs such as food, clothing, housing, clean water,

and education, but also includes opportunities for decent work and improved overall quality of life. By strengthening income stability and access to basic services, farmers are expected to achieve a social position on an equal footing with the rest of society, so that they not only survive on livestock activities, but are also able to develop economically.

In the cattle farmer group, the strategy that has developed so far is still dominated by the independent business pattern, where livestock is positioned as a long-term asset or family savings. Many farmers rely on the proceeds from cattle sales to finance their children's education or major household needs, while their main jobs remain in the agricultural sector. This condition shows the need for a push towards a more organized business model, such as the formation of farmer groups or cooperatives, so that access to capital, technology, and markets can increase. If the breeding pattern is carried out individually, the opportunities to improve productivity, business efficiency, and shared welfare tend to be limited because each breeder must bear the risks, costs, and management on their own.

Many people are also involved, one of which is in community service activities to improve livestock business results through assistance in making feed that utilizes local resources and the provision of animal health services in Manamas Village, Naibenu District, North Central Timor Regency. Farmers in this area generally face obstacles in the form of a lack of understanding of nutritionally balanced feed formulations and limited livestock health services that can be accessed regularly. Activities are carried out through counseling sessions, direct training, demonstrations of fermented feed processing, and animal health checks carried out with veterinary medical personnel (Sio et al., 2025). Then the service activities of beef cattle farmers in Pelemrejo Village, Andong District, Boyolali Regency, several problems found related to feed management include the lack of understanding of farmers about the quality of feed materials and inaccuracies in feeding so as to trigger waste. For this reason, service activities are carried out through counseling and training which include an introduction to feed quality, feed processing and storage techniques, as well as feeding methods that meet the needs of livestock (Ratriyanto et al., 2021). Therefore, a more economical, inclusive, and easy-to-use solution is needed to overcome these problems, namely through NutriFarm.

3.4 Opportunities for digital transformation of livestock towards food independence

The Livestock Era 4.0 offers a great opportunity for Indonesia to overcome various classic problems in the livestock sector. The concept of precision livestock *farming* that is developing globally emphasizes the use of digital technologies such as sensors, IoT, and data analysis to improve productivity, health, and efficiency of livestock farming (Berckmans, 2017). Through this precision approach, farmers can monitor livestock needs in real time and develop more targeted maintenance strategies (Wolfert et al., 2017). However, the challenge for Indonesia is how these technological trends can be adapted by small-medium farmers who are the backbone of national production. This is where the role of digital applications like NutriFarm becomes relevant. The SMART goal of NutriFarm shown in (Fig.2).

Specific is designed to provide targeted digital solutions for smallholder farmers, especially in optimizing feed formulation, nutrition monitoring, and livestock management. This approach ensures that each feature works towards the same goal, which is to help farmers make more informed and data-driven decisions. With a clear focus, this technology is a real tool for farmers in improving the efficiency of their livestock business. Measurable can be measured through indicators of livestock growth, feed consumption, and quantitatively recorded milk or meat production. Features such as Nutri Check, Feed Log, and FeedCam are measuring tools that provide daily and periodic data, so that livestock development can be monitored accurately. The results of this measurement make it easier for farmers and companions to evaluate the effectiveness of the use of technology.

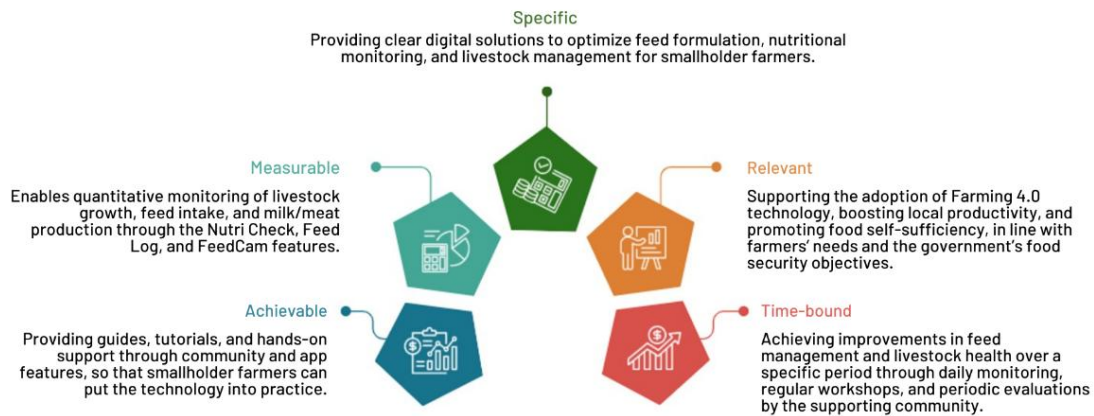


Fig. 2. NutriFarm's SMART objectives

Achievable is designed to be realistically implemented by smallholder farmers through simple guidance, practical tutorials, and mentoring from the community. The app not only presents the technology but also brings it closer to the user through easy-to-understand materials and hands-on support. Thus, the target of applying technology can be achieved without burdening farmers with complicated processes. Relevant is in line with the needs of the modern livestock sector, especially in supporting the transformation towards Animal Husbandry 4.0. This system helps increase local productivity, strengthen food independence, and address national food security challenges. This relevance ensures that the technology applied is not only innovative, but also really important for the development of smallholder farmers.

Time-bound, the implementation of Smart NutriFarm is directed to produce real changes within a certain period through daily monitoring, periodic workshops, and regular evaluations from the companion community. Clear time targets help ensure that improvements in feed management and livestock health are not only planned but also realized in a measurable manner. With the implementation deadline, the entire process becomes more focused, directed, and can be evaluated on an ongoing basis. The app represents a simple form of precision livestock farming that can be used by smallholder farmers, by combining feed data analysis, livestock health, and maintenance management in a single platform. Thus, NutriFarm not only brings the spirit of global digitalization to the local level but also becomes a bridge to accelerate the transformation towards food independence and reduced import dependence.

3.5 NutriFarm: Solution to increase livestock productivity

NutriFarm is here as an innovative solution that integrates digital technology in the people's livestock system. This application has various features designed to assist farmers in compiling more effective and efficient feed formulations. The following is an overview of the NutriFarm application in (Fig. 3).

A description of the features contained in the application is in the Appendix. Some of the key features offered by NutriFarm include: The Nutri Mix feature is designed as the core of the process of preparing efficient and measurable feed rations. Through the automatic ration calculator, farmers only need to enter basic information such as breed, age, weight, and maintenance goals, then the system will generate recommendations for the most appropriate feed formulation. Not only that, but this feature also provides a list of local feed ingredients that are easy to reach as well as more economical alternatives to reduce production costs. It also includes an estimated ration cost, complete with price predictions and the distance of the provider's stores, so that farmers can choose the source of feed materials with the best value.

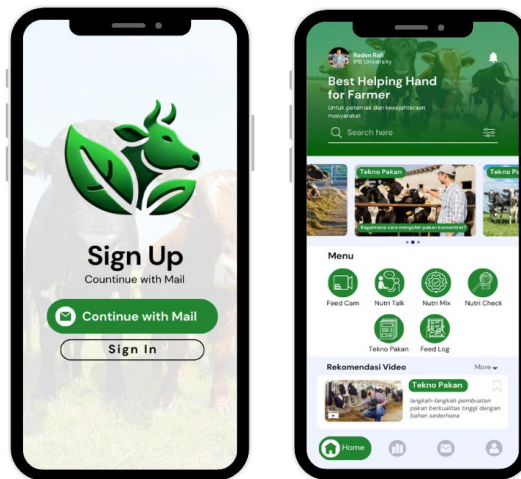


Fig. 2. NutriFarm's SMART objectives

The Nutri Check feature functions as an evaluation tool for the nutritional content of the feed that is being used. This system displays the levels of protein, energy, fiber, vitamins, and minerals from each feed ingredient, then provides recommendations when certain nutritional deficiencies or excess are found. This feature is even more comprehensive with growth and production graphs, which project how the chosen feed formulation will affect the body weight of livestock or milk production over a certain period. Thus, farmers can assess the effectiveness of rations more accurately.

The FeedCam feature is a practical solution for farmers in recognizing plants that have the potential to be used as animal feed. Simply by taking photos of the plants around the farm site, the system will identify the plant name, its type, as well as the main nutrient content contained in it. This technology allows farmers to make optimal use of local resources, especially in areas that are rich in vegetation but have not been fully utilized as alternative feed materials.

The Feed Tech feature provides a comprehensive guide to various feed processing techniques. It contains step-by-step tutorials on fermentation, silage making, and other processing methods that can improve the shelf life and digestibility of feed. In addition to informative articles, this feature is also equipped with educational videos that make it easier for farmers to understand the process visually. Information about simple equipment such as grass mowers or feed dryers is also included to help farmers improve the efficiency and quality of the feed they produce.

The Feed Log feature acts as a tool for recording and monitoring daily animal feed consumption. Through this feature, farmers can document the amount of feed given each day so that the diet of livestock can be better controlled. If there are indications of nutritional deficiencies or abnormal changes in consumption, the system will provide automatic notifications so that farmers can immediately take corrective steps. This feature supports more precise and responsive livestock management.

The NutriTalk feature functions as a space for interaction and collaboration between livestock actors. Through this community chat platform, farmers can exchange experiences, discuss feed formulations, or share solutions related to problems in the field. In addition to community discussions, this feature also opens access to direct consultation with livestock nutrition experts, similar to the teleconsultation service model, so that farmers can get professional advice without having to come to the service center. The Voice Guidance feature is present as a language aid that makes it easier for farmers who are not used to reading long texts or using formal Indonesian. With voice guidance in the local language, farmers can follow the application instructions more easily and naturally. This feature helps ensure that important information about feed and livestock management is accessible to all farmers without language barriers.

The Feedback feature provides a space for farmers to convey constraints, user experience, and application development ideas directly. With this two-way communication, application providers can continue to customize features and services based on real needs in the field. This ensures the application develops in a relevant way and remains beneficial to farmers in the long run. With various features offered, NutriFarm not only provides solutions for farmers in formulating efficient feed formulations, but also improves livestock welfare, optimizes local resources, and reduces dependence on feed material imports. This will be directly related to the success of the government's free nutritious meal program, by ensuring that domestic meat and dairy production can increase and that animal protein is available at a more affordable price.

3.6 NutriFarm community synergy as a companion to the digitalization bridge for farmers

The establishment of a digital farmer companion community has the main goal of helping farmers understand the use of NutriFarm application directly. This community structure involves a wide range of stakeholders. From universities, there are lecturers, students, and researchers who provide technical education and disseminate the latest innovations. The government is also present to ensure that this program runs evenly. Meanwhile, local farmers are the main members, who are not only recipients of guidance, but also have the potential to become role models for other farmers around them.

The activity is in the form of routine field visits, where the companion comes to the cage to guide the use of applications and supporting technology. In addition, there are workshops and digital clinics on livestock with simple modules to make them easy to understand. Joint monitoring and evaluation are also carried out to monitor the development of the use of NutriFarm, provide feedback, and assist the breeder adaptation process. The NutriFarm adoption process can also take place faster due to face-to-face assistance. In the end, farmers' trust in Livestock 4.0 technology will be stronger, making this community a driver of digital transformation in the livestock sector.

Mentoring activities are carried out regularly through cage visits, application guidance sessions, and digital clinics with simple modules that are easy to follow. There are also thematic workshops featuring case studies, hands-on practice, and Q&A sessions. Periodic evaluations are carried out together so that the development of NutriFarm adoption can be monitored, obstacles can be overcome faster, and the adaptation process runs more naturally. With a consistent face-to-face approach, farmers' trust in technology will strengthen and form a wave of digital transformation that grows from village to village.

Expanding the impact of mentoring, this program is combined with the Village Enterprise Catalyst (VEC) scheme, a model for developing a village business ecosystem that emphasizes independence, improving the quality of human resources, and strengthening the value chain of local superior products. VEC is presented as a framework that brings together training, mentoring, technology adoption, and market access expansion. The VEC model consists of three stages that are connected from upstream to downstream.

The first stage is One Village One Product Focus, which is the determination of superior products in a village. At this stage, local potential mapping is carried out, identification of parties to be involved, and the formulation of a collaborative product development strategy. The second stage is One Village One Innovation, which is the value-added development phase. Through this stage, product quality is improved, appropriate technology is applied, and innovation integration that supports business efficiency so that superior products have a unique and competitive character. The third stage is One Village One Marketplace, which is the process of expanding market access. Activities include strengthening branding, digital marketing, preparation of promotional materials, and facilitating connections with local and foreign buyers. Products that already have added value are directed to be able to penetrate a wider and sustainable market. The VEC program itself departs from the need to build a structured, measurable, and sustainable village business ecosystem.

This approach emphasizes community collaboration, technology utilization, and capacity building of villagers to be able to become the main actors in local economic growth.

If the community of digital breeders becomes the motor of technological transformation in the livestock sector, then VEC becomes a wing to strengthen the village economy through superior products, innovation, and markets. The two complement each other, forming an ecosystem that makes the village not only ready to adapt to technology, but also able to develop through innovation that continues to grow.

3.7 Advantages of NutriFarm community and application in accelerating and assisting innovation to farmers

The NutriFarm community and application have the main advantages as a means of accelerating innovation and sustainable assistance for farmers. Effective and economical feed formulation, Nutri Mix helps to automatically formulate rations according to livestock data, while reducing costs by utilizing local feed ingredients. Precision nutrition monitoring, Nutri Check and Feed Log facilitate nutrition control and provide early warning, supporting the concept of precision livestock farming. Optimization of local resources, FeedCam recognizes surrounding plants and their nutritional content, so farmers can make the most of local potential. Education and technology transfer, Feed Techno and its companion communities provide guides, workshops, and digital clinics to improve farmers' skills. Community support and expert consulting, NutriTalk and mentoring from universities and governments create a digital ecosystem that accelerates technology adoption. There is a feedback feature for two-way communication in the community. Easy access with voice guidance features and offline mode if the internet is not stable. This application involves the government for cooperation with government programs and quick access to information in monitoring feed price data that is always accurate.

3.8 Collaborative ecosystem: Pentahelix collaboration and information flows in implementation

In the implementation of NutriFarm, *the collaboration of Pentahelix* in (fig. 4) plays an important role in ensuring that the digital transformation of livestock runs effectively. The central and regional governments play a role as policy makers as well as facilitators of the implementation of digital technology in the livestock sector, with support in the form of regulations, food security monitoring, and mentoring programs so that NutriFarm's innovations can be adopted equally by smallholder farmers. Universities and academics, including lecturers, students, and researchers, provide technical education and share the latest innovations related to precision farming, as well as conduct research and development of the latest science-based application features so that NutriFarm is always relevant to field needs.



Fig. 4. Pentahelix Collaboration in NutriFarm

Smallholder farmers as beneficiaries become the main users of the NutriFarm application, apply digital technology in livestock management, receive direct benefits such

as optimal feed formulation and nutrition monitoring, and act as role models for other farmers in the community. Feed and technology companies support through the provision of quality feed materials and digital infrastructure, as well as working together in the development of application features to ensure the solutions provided are practical and according to field needs. Meanwhile, communities and accompanying institutions connect farmers with organizers and experts, providing direct guidance in the field through workshops, digital clinics, and regular visits, so that technology adoption runs smoothly and continuous feedback can be utilized for further application development.

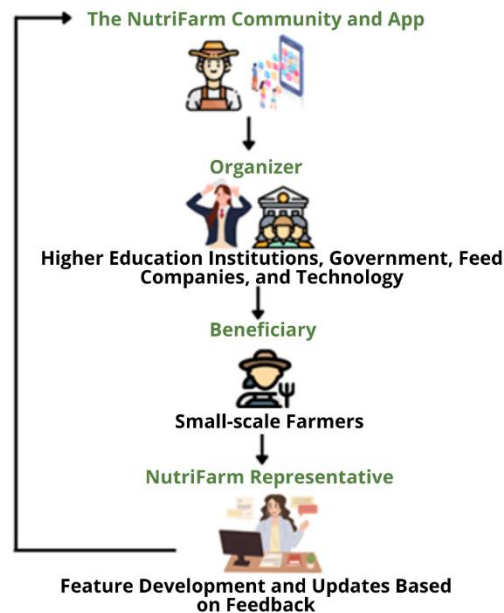


Fig. 5. NutriFarm information flow

NutriFarm's information flow as shown in (fig. 5) starts from the community and the app, which provides digital platforms, features, and guidance, then is channeled to organizers such as governments, universities, and feed & technology companies to be facilitated, guided, and monitored. Furthermore, this innovation is passed on to the beneficiaries, namely smallholder farmers, who apply digital technology, utilizing optimal feed formulation, nutrition monitoring, and feed processing education. Farmers also play the role of key collaborators by sharing experiences and interacting through NutriTalk, while input and feedback from collaborators return to the NutriFarm app for further feature development, forming a continuous information cycle that accelerates the adoption of Farms 4.0.

The companion community and the NutriFarm app serve as an ever-moving knowledge hub, where digital features, technical guidance, and field practice complement each other. The support of organizers such as local governments, educational institutions, and technology partners strengthens this process through facilitation, guidance, and consistent monitoring. When smallholder farmers began to take advantage of automated feed formulations, nutritional analysis, feed processing, and NutriTalk discussion forums, their experience became an important part of the development process. Every story, obstacle, and success in the cage turns into living material that enriches the innovation ecosystem. The role of farmers does not stop as a beneficiary, but develops into a mover, who shares good practices with other farmers.

All of these dynamics are assembled in a design-based research framework, where technology and mentoring develop through a repetitive cycle based on real experience. The decision to update features, simplify the view, add guides, or customize training modules is not made from assumptions, but rather from the results of live field testing. Companions, developers, and breeders work in a pattern of designing, testing, reflecting, and then

refining. This approach ensures that NutriFarm grows as a system that is responsive, adaptive, and truly grounded in the context of smallholder farming, while accelerating the maturation of technology towards Farm 4.0 practices that are more ready to be widely implemented.

The main source of funding for the NutriFarm program comes from corporate CSR, especially feed and technology companies, which provide funding for digital infrastructure and feed materials. The scheme allows funds to be made available faster, provides incentives for companies through improved image and social responsibility, and is flexible for field innovation. In addition, the government can act as a source of support through grants, subsidies, or digital infrastructure facilities, providing legitimacy and oversight while ensuring that programs reach underserved areas, but are still managed like CSR programs so that the flow is simple. With this hybrid model, funding becomes sustainable because it is not entirely dependent on public budgets, private sector participation drives innovation and efficiency, and the government continues to play its role as a facilitator and regulator to keep programs on target.

4. Conclusions

The presence of NutriFarm is a strategic step in an effort to increase national livestock productivity and reduce dependence on meat and dairy imports. This application offers a practical and technology-based solution to answer the fundamental problem in the people's livestock system, namely the low efficiency of feed formulation. Through features that allow precise ration preparation, monitoring of nutritional adequacy, utilization of local feed ingredients, and educational assistance for farmers, NutriFarm plays a role in improving the quality of feed management and livestock health. Thus, farmers can achieve cost efficiency, improve production performance, and increase the competitiveness of their livestock business.

The implementation of NutriFarm also has important implications for national food security. Increasing domestic animal protein production will strengthen Indonesia's capacity to meet the nutritional needs of the community, especially in supporting the government's free nutritious meal program. When domestic production increases sustainably, dependence on imports can be reduced, so that the stability of meat and dairy supply can be maintained. This shows that strengthening the livestock production system at the upstream level plays an important role in ensuring the sustainability of food programs at the downstream level.

In addition to the technical aspect, NutriFarm encourages social transformation in smallholder farms through increasing technological literacy and collaboration between stakeholders. An approach that integrates elements of government, academia, industry players, and the farming community makes NutriFarm an adaptive and sustainable innovation model. With the pentahelix synergy, livestock development is no longer only based on temporary assistance programs but is directed at capacity building and long-term independence. NutriFarm is not just an application, but an instrument of change in the national livestock system. Through digitalization, sustainable mentoring, and optimization of local resources, NutriFarm has the potential to become the foundation for strengthening Indonesia's animal food security. Consistent and measurable implementation will bring Indonesia closer to food independence, farmers' welfare, and improving the nutritional quality of the community nationally.

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Author Contribution

Conceptualization, M.R.I. and R.R.; Methodology, M.R.I.; Software, — ; Validation, M.R.I. and R.R.; Formal Analysis, M.R.I.; Investigation, M.R.I. and R.R.; Resources, M.R.I. and R.R.; Data Curation, M.R.I.; Writing – Original Draft Preparation, M.R.I.; Writing – Review & Editing, M.R.I. and R.R.; Visualization, M.R.I.) drafted the main content of the manuscript, developed the methodology, prepared the abstract, expanded the manuscript to meet the required 6000-word target, and completed the majority of citation additions until reaching 32 references. R.R. prepared the introduction and conclusion, contributed to content expansion, added references, and translated the manuscript into English. Both authors jointly revised, edited, and expanded multiple sections, including the introduction, main content, and conclusion, to meet journal requirements.

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