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# Risk analysis and production dynamics of smallholder pig farming in rural areas of North Sulawesi

## *Analisis resiko dan dinamika produksi usaha ternak babi rakyat di daerah pedesaan Sulawesi Utara*

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**ABSTRACT**

Smallholder pig farming in rural areas of North Sulawesi important role in food security, household economy, and socio-cultural of local communities. However, this sector faces various risks. The aims to analyze production dynamics and identify risk factors that affect the sustainability of smallholder pig farming in rural areas. The research employed a quantitative approach through a survey of 604 farmers (having 3-4 sows/farmer). Data analyzed using multiple linear regression. The results showed that labor, the cage area, quantity of medicines, farm model, and farm location in rural areas significantly influenced pig production. The breeding model resulted in higher production than the combined pig farming model and tended to have lower production risks. Pig production in rural areas is also higher than in suburban areas. Disease risk is the main cause of losses, with production and income declines reaching 182.9% in the breeding model and 303.4% in the combined model. In conclusion, the breeding model resulted in higher production and tends to have lower production risks, particularly disease-related risks that directly affect productivity and farm continuity. These risks significantly reduce household production and income, highlighting the strong relationship between production dynamics, risk levels, and the economic stability of rural pig farmers.

*Kata kunci:*
*Sulawesi utara*
*Peternakan babi*
*Dinamika produksi*
*Resiko*
*Peternak kecil*

**ABSTRAK**

*Peternakan babi skala kecil di kawasan pedesaan Sulawesi Utara memiliki peran penting dalam ketahanan pangan, ekonomi rumah tangga, serta pemenuhan kebutuhan sosial budaya masyarakat. Namun, sektor ini menghadapi berbagai risiko. Penelitian ini bertujuan untuk menganalisis dinamika produksi serta mengidentifikasi faktor risiko yang memengaruhi keberlanjutan peternakan babi skala kecil di daerah pedesaan. Metode penelitian menggunakan pendekatan kuantitatif melalui survei terhadap 604 peternak (semua peternak yang memiliki 3-4 ekor induk). Data dianalisis menggunakan regresi linier berganda. Hasil penelitian menunjukkan bahwa tenaga kerja, luas kandang, jumlah obat-obatan, model peternakan dan lokasi peternakan di wilayah pedesaan berpengaruh signifikan terhadap produksi ternak. Model pembibitan menghasilkan produksi lebih tinggi dibandingkan model peternakan babi kombinasi, dan memiliki risiko produksi yang lebih rendah. Produksi babi di pedesaan juga lebih tinggi daripada di wilayah pinggiran kota. Risiko penyakit menjadi penyebab utama kerugian, dengan penurunan produksi dan pendapatan mencapai 182,9% pada model pembibitan dan 303,4% pada model kombinasi. Kesimpulannya yaitu di pedesaan Sulawesi Utara model pembiakan menghasilkan produksi yang lebih tinggi dan cenderung memiliki risiko produksi yang lebih rendah, terutama risiko terkait penyakit yang secara langsung sehingga memengaruhi produktivitas dan keberlanjutan peternakan. Risiko-risiko ini secara signifikan mengurangi produksi dan pendapatan rumah tangga yang berhubungan dengan dinamika produksi, tingkat risiko, dan stabilitas ekonomi peternak babi di pedesaan.*

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## INTRODUCTION

Pig farming has long been an integral part of rural life in Indonesia, serving not only as a source of animal protein but also as savings and a safety net for household income. In North Sulawesi, particularly in the Minahasa region, household-based pig farming has been practiced for generations and has become deeply rooted in local culture, especially in traditional ceremonies and religious practices (Manese et al., 2021; Santa et al, 2018). Nevertheless, smallholder pig farming in this area is still largely managed using traditional methods with limited resources.

This sector has faced various challenges that threaten its sustainability. First, the heavy reliance on commercial feed with highly fluctuating prices often burdens production costs. This condition pushes farmers to reduce the amount of feed provided, which in turn leads to nutritional deficiencies, decreased productivity, and declining household income (Santa et al., 2018; Tian et al., 2015). Second, external shocks such as the COVID-19 pandemic in 2020 caused pork demand to drop by up to 50%, directly impacting livestock populations (Marchant-Forde et al., 2020). Third, in 2023, the outbreak of African Swine Fever (ASF) resulted in mass mortality of pigs, reducing production by as much as 80% (Viltrop et al., 2021).

Therefore, systematic and early identification of risks, including feed price volatility, demand shocks, and disease risks, is crucial to guide daily decisions at the farm and upstream policies. At the same time, the implementation of dynamic productive restructuring accelerated through rapid adjustments to ration composition and feeding schedules, restructuring of reproductive cycles and stocking densities, modularization of harvesting and marketing patterns, diversification of feed raw material sources, and adaptive biosecurity and early warning protocols, so that livestock systems remain resilient and responsive to change.

In addition, this sector faces structural problems, such as the declining agricultural workforce. Most pig farmers today are of advanced age, while the number of new farming households continues to decrease. This trend poses a serious risk to future production capacity (Santa et al., 2021). The combination of these factors indicates that smallholder pig farming in North Sulawesi is highly vulnerable to risks related to production, income, as well as environmental and socio-cultural pressures.

Previous studies have analyzed production risks, marketing risks, and farmers risk preferences (Mappa et al., 2022; Erdyana et al., 2021; Pietrosemoli et al., 2020; Vinanda et al., 2016; Soltész et al., 2014). However, most of these studies remain partial and have yet to integrate production, risk, and sustainability analysis into a holistic framework. In fact, comprehensive strategies for risk identification, measurement, and management can assist farmers, researchers, and policymakers in formulating more effective solutions (Gregolin et al., 2023; Manevska-Tasevska et al., 2017).

Based on these conditions, this study aims to analyze the factors influencing smallholder pig production (having 3-4 sows/farmer), identify the types of risks faced by farmers, and assess the sustainability of farming practices within the local cultural context. This research differs from previous studies by emphasizing an integrated analysis of production dynamics, risks, and farmers adaptive strategies in managing uncertainty. The findings are expected to contribute to the development of a more resilient, efficient, and sustainable smallholder pig farming system in rural North Sulawesi.

## MATERIALS AND METHODS

### The Site, Sample, and Data Collecting Technique

This study was conducted in North Sulawesi Province, which has the second largest pig population in Indonesia, focusing on smallholder pig farming in rural and urban areas during April–June 2024. The sample subdistricts were determined using purposive sampling Sugiyono (2020) based on the criteria of having the highest pig population and being affected by ASF. Based on these criteria, Kawangkoan and Sonder Subdistricts in Minahasa Regency were selected as rural samples, while West Tomohon Subdistrict in Tomohon City and East Kotamobagu Subdistrict in Kotamobagu City were selected as urban samples.

The respondents were subsequently

determined using total sampling Sugiyono (2020), consisting of pig farmers engaged in the breeding model as well as the combined breeding–fattening model. A total of 604 pig farmers from the study locations were included in the research through total sampling, representing the entire farmer population in the study area. Of the total respondents, 429 farmers applied the breeding model, while 175 farmers practiced the breeding–fattening combination model.

Based on the location of pig pens, 490 farmers raised pigs in rural areas and 114 farmers in suburban areas, with smallholder farming systems as the dominant production model. In addition, both farming models (breeding and breeding–fattening combination) were included to ensure that the research findings reflect the real conditions of smallholder pig farming in North Sulawesi. The data used consisted of primary data related to pig production and secondary data sourced from journals and institutional publications.

## Data Analysis

Data analysis on factors that influence pig production and farmers risk preferences using the Just Pope function model Tembei et al. (2019) explains that the resulting output is influenced by production and risk factors.

$$Y = f(x,\beta) + g(x,\alpha)\varepsilon$$

Information:

- Y = results achieved
- f(x) = average production function
- g(x) = risk function or variance function
- xj = input used
- β = parameters of the estimated production function
- α = parameter of the estimated risk function
- ε = error term with E(ε)=0 and var(ε)= σε2

The Just Pope function model requires that no restrictions be placed on the risk effect by using the condition that ∂var(y)/∂xj = ∂g(x)2/∂xj, which has a possible value of ≤ 0, or ≥ 0 which indicates that the input This is risk increasing or risk decreasing towards the production risks faced by farmers. A Cobb-Douglas type function model is assumed to be used to analyze the production function and risk function of pig farming. Next, the Cobb-Douglas model is regressed using the Ordinary least square (OLS) method (Gujarati et al., 2013). The analysis method is as follows:

$$Ln\, f(x) = ln\alpha_0 + \alpha_1 lnPKN + \alpha_2 lnTK + \alpha_3 lnJO + \alpha_4 lnLK + d_1D_1 + d_2D_2 + \varepsilon$$
$$Ln\, g(x) = ln\beta_0 + \beta_1 lnPKN + \beta_2 lnTK + \beta_3 lnJO + \beta_4 lnLK + d_1D_1 + d_2D_2 + \varepsilon$$

Information:

- f(x) = pig production function (kg/year)
- g(x) = risk function (kg/year)
- α0; β0= intercept
- βi; αi = regression coefficient (estimated parameter)
- ε = error term/disturbance error/ disruption
- PKN = feed (kg/year)
- TK = labour (man-days/year)
- JO = quantity of medicines (dose/year)
- LK = cage area (m2)
- D1 = location dummy (rural area = 1 and suburban = 0)
- D2 = pig farming model dummy (breeding model = 1 and combined breeding-fattening model = 0)

The analysis of farmer risk preferences assumes that farmers try to maximize utility, and utility maximization is approached by maximizing income in pig farming. Farmers get production results at price level p. The maximization of farmer utility is utility U from profit π:

$$\text{Max } U(\pi) \text{ with } \pi = p.y - r.x - C$$

Information:

- π = profit of pig farming
- r = input price
- x = number of inputs used
- C = fixed costs of pig farming
- p = output price
- y = output

The utility function for pig farmers [U(πo)] is formulated:

$$U(\pi o) = p.f(PKN, TK, JO, LK) + p.g(PKN, TK, JO, LK) - ri(PKN, TK, JO, LK) - C\,(LK)$$

Information:

- U(πo) = pig farmer's utility
- f(x) = production function
- g(x) = risk function
- p = output price (IDR)
- ri = price of input i (IDR)

xi = number of inputs i
C = fixed costs of pig farming (IDR)
PKN = feed (kg/year)
TK = labour (man-days/year)
JO = quantity of medicines (dose/year)
LK = cage area (m2)

To analyze the risk preference value of breeders by adopting Arrow-Pratt absolute risk averse (AR) as follows (Tembei et al., 2019):

$$AR = \frac{U,(\pi i)}{U,,(\pi i)}$$

According to Tembei et al. (2019), farmers can be said to be (1) risk-averse if AR > 0, (2) risk-takers if AR < 0, and (3) risk-neutral if AR = 0. The sustainable pig farming model was built to reduce the risk of pig farmers based on the analysis of the risks of pig farming.

## RESULTS AND DISCUSSION

### Production and Risk Dynamics in Smallholder Pig Farming

Pig production is the amount of meat produced and sold by pig farming through the breeding and combined breeding-fattening models. Pig production in the breeding model is calculated based on the number of piglets sold multiplied by the live weight of the piglets (kg/year). Pig production in the combined breeding-fattening model is calculated based on the number of fattening pigs sold multiplied by the live weight of the pigs (kg/year). Regression analysis of factors affecting pig production is described in Table 1. The regression analysis results of factors affecting pig production in Table 1 using the just pope model have considered risk factors for pig production, which is different from previous studies (Manese et al., 2021). The results of observations of regression analysis of factors affecting pig farming production and risks are listed in Table 1.

The results of the regression analysis in Table 1 show that the production function model exhibits a very high fit ($R^2$ = 0.998) and is simultaneously significant (F-statistic = 52,923.43; Sig. F = 0.000). This indicates that the estimated variables are almost entirely able to explain production variations. Meanwhile, the risk function model is also simultaneously significant (F-statistic = 23.844; Sig. F = 0.000), but its explanatory power is relatively low ($R^2$ = 0.193), indicating that there are still other risk factors outside the model. For partial tests, the variables that significantly influence pig production are labor, cage area, quantity of medicines, farming model, and farm locations in rural areas, while the variable that is not significant is feed. For partial tests, the variables that significantly influence the risk function model are labor and cages area, while the variables that are not significant are fed, quantity of medicines, farming model, and farm locations in rural areas.

Table 1 shows that the labor variable

Table 1. Results of regression analysis of factors affecting pig farming production and risks

| No | Information | Regression Coefficients | | | |
|---|---|---|---|---|---|
| | | Production Function | | Risk Function | |
| | | Coefficients | P-value | Coefficients | P-value |
| 1 | Constant | 4.664 | 0.000 | -0.025 | 0.009 |
| 2 | Feed | 0.004$^{ns}$ | 0.567 | 0.0004$^{ns}$ | 0.511 |
| 3 | Labour | 0.076*** | 0.001 | 0.008*** | 0.000 |
| 4 | Cages area | 0.890*** | 0.000 | -0.004*** | 0.000 |
| 5 | Quantity of medicines | 0.025*** | 0.006 | -0.005 $^{ns}$ | 0.600 |
| 6 | Farming model | 0.026*** | 0.000 | -0.003 $^{ns}$ | 0.493 |
| 7 | Farm locations in rural areas | 0.009** | 0.048 | -0.002 $^{ns}$ | 0.675 |
| 8 | R2 | 0.998 | | 0.193 | |
| 9 | F-statistic | 52923,430 | | 23,844 | |
| 10 | Significance F | 0.000 | | 0.000 | |

Note: Significant levels (*** P<0.01; ** P<0.05; $^{ns}$ Not Significant)

has a highly significant effect (P<0.01) on pig production, meaning that if the use of farmer labor is increased by 1%, pig production will increase by 0.07%. The labor force is responsible for managing the pig farm and acting as a manager. The labor force is required to understand the nutritional needs of pigs for each age and stage of rearing, be skilled at naturally mating pigs, be skilled at caring for piglets (trimming teeth and nails), and even understand the signs of sick pigs (Woran et al., 2020). This condition explains that pig production can be achieved if people work and manage the pig farm. The decrease in the number of pig farmers caused a decrease in the amount of pig production in North Sulawesi, resulting in the North Sulawesi Government importing pork from Bali in July 2024 to ensure the availability of pork for the local community. This situation is in accordance with the research results showing that a decrease in the number of workers causes a reduction in production (Woran et al., 2020; Vinanda et al., 2016).

The results of statistical analysis in Table 1 show that the variable of the quantity of medicines has a very significant effect (P<0.01) on pig production, meaning that if the use of medicines by farmers is increased by 1%, pig production will increase by 0.02%. Medicines function to maintain the health of livestock so that they do not get sick. Pig farmers are obedient in giving medications to pigs to keep their bodies healthy. Healthy pigs cause pigs to grow well so that maximum pig production can be achieved. This is in line with several studies that giving pig medicines according to dosage is an effort by farmers to prevent pigs from getting sick (Chah et al., 2016; Thanapongtharm et al., 2016; Tian et al., 2015).

Pig pens are a place to raise pigs and produce pigs. The results of the statistical analysis in Table 1 show that the variable of the cages area has a very significant effect (P<0.01) on pig production, meaning that if farmers increase the cage area by 1%, pig production will increase by 0.89%. The study results showed that the cage's area adjusts to the pig production phase. The average ownership of the cage area is 130-150 m2/farmer, 80% of farmers build cages for sows and fattening pigs, while 20% of farmers build cages for sows. There are 80% of pig cages that farmers have used for more than 20 years. This is in line with several studies that state that the area of the cage positively affects the amount of pig production (Ocepek et al., 2022; Fakihuddin et al., 2020; Meyer-Hamme et al., 2016; ).

The variable of farm location in rural areas showed a positive and significant effect at the 5% level on pig production (P<0.05). This means that farms located in rural areas have approximately 0.9% higher production than those in sub-urban areas, all other things being equal. Generally, pig pens are built behind the farmer's house. The difference is that in rural areas, the pens tend to be adjacent to pens owned by other farmers, while in sub-urban areas, the pens are more often adjacent to the homes of residents who are not pig farmers. Initially, farmers in sub-urban areas also built pens behind their houses because there was still available vacant land nearby. However, with population growth, sub-urban areas generally became targets for residential development, so pig pens became closer to non-farmer settlements. This is in line with Peplinski (2020) findings that farming/storage businesses in sub-urban areas began to decline with urban development or expansion. Since 2014, communities in several areas in North Sulawesi have also complained about the impact of pig pen waste on the environment, which causes environmental pollution. This situation is like that experienced in several pig farms across Indonesia (Marani et al., 2023; Sinurat, 2019). Therefore, pig farmers in sub-urban areas are often reminded not to increase their livestock population to minimize the potential for environmental pollution.

Pig farmers in the research location applied two of the three pig farming models in Indonesia, the breeding model and the combination breeding-fattening model. The statistical analysis results in Table 1 show that the farming model variable has a positive and highly significant effect on production. This means that the purely breeding business unit has approximately 2.6% higher production than the combined breeding-fattening model, ceteris paribus. Pig production in the breeding model was obtained from selling 1-month-old weaned piglets with an average body weight of 15 kg/head/

period. Pig production from the combination breeding-fattening model was obtained from the sale of 1-month-old weaned piglets (average body weight of 15 kg/head/period) plus the sale of fattening pigs (average body weight of 95-100 kg/head/period). This study used total sampling of all pig farms in rural and sub-urban areas within a defined sampling framework. This approach included all units meeting the inclusion criteria in both areas, ensuring that the final composition (429 breeding units; 175 combined units) reflects the actual population distribution in the study area. However, the overall analysis uses robust standard errors to anticipate heteroscedasticity and differences in group sizes. With a total sampling scheme in rural and sub-urban areas, the sample composition and operational characteristics of the business units are reflected as they are in the data: breeding (output of weaned calves aged ±1 month) and 2 times mated sows in 1 year, have a faster turnover so that the throughput per period is higher than the combination model that holds some stock until it weighs 95–100 kg before being sold. Such sample conditions are consistently reflected in the estimation results, where the coefficient of the breeding model variable is higher and significant than the combination model, ceteris paribus. This situation is in accordance with Thoma et al. (2024) that operationally, the breeding unit releases output at the weaning phase (±3–4 weeks), so that the pen and workforce quickly rotate to the next batch; conversely, in the combination, some calves are held until the grower–finisher which requires an additional ±16–17 weeks, so that the effective capacity and frequency of product output per year decrease.

Although theoretically, feed is the largest cost component and the primary determinant of livestock performance, the results in Table 1 indicate that feed variables did not significantly impact production (P=0.567). The results indicate that farmers at the study site currently use relatively uniform types of manufactured feed. Previously, they mixed their own feed (bran, corn, and concentrate), but rising prices and limited availability of bran and corn prompted a shift to commercial feed. Furthermore, the feed rate reached approximately 2.5 kg per feed, twice daily for the sows (±5 kg/head/day), which is likely to exceed daily requirements during some stages of the rearing process. These results align with research Li et al. (2025) that suggests the combination of feed homogeneity and the possibility of overfeeding has the potential to cause a threshold effect/diminishing return. Therefore, the feed variation recorded in this study is insufficient to explain the variation in output, which aligns with the regression results showing an insignificant feed coefficient.

Based on the results of the risk function regression analysis in Table 1, it is known that partially, the labor and cage area variables have a very significant effect on the risk of pig production. Table 1 shows that the labor variable is risk-increasing for pig production, meaning that labor is at risk of increasing pig production. This is in line with Vinanda et al. (2016) that the increasing number of livestock production and population requires more labor and precision in management for meat production. Based on the results of the study, it is known that the number of workers in pig farming has decreased, partly due to low farmer income so that they are encouraged to sell agricultural land to meet their needs, changes in generations who are not interested and are not physically trained to work on farms. This situation follows the results of White (2012), which states that the current young generation tends to choose to work in the service sector, which quickly earns income. The decline in the number of pigs produced due to the lack of labor in pig farming will cause a pork deficit because the need for pork is increasing daily along with the increasing population.

The results of the risk function regression analysis in Table 1 show that the cages area variable is at risk of decreasing pig production, meaning that the cages are at risk of reducing the amount of pig production. This condition follows the results of Vinanda et al. (2016) that the cage area has a risk of reducing the amount of output. Pig produces meat and waste, impacting the environment's foul odor around the cage. Most pig farmers do not collect and process pig waste; instead, they dispose of it directly into the river. This follows several research results Manese et al. (2021; Santa et al., 2021; Yan et al., 2019), showing that pig farmers do not process pig waste. This condition is the main reason for residents around the cage of pigs from building

pig pens around residents' houses. Therefore, pig pens used by pig farmers are generally built and used for more than 20 years.

The insignificant feed variable influencing the risk function regression results, according to research results, is due to the homogeneity of commercial feed types in the field and the aggregate feed indicators (emphasizing quantity rather than formulation accuracy/ phase). According to Trabachini et al. (2025) adjusting the composition and daily feed quantity according to the needs of each phase/ pig is more effective in improving performance consistency and reducing waste. This factor is not implemented by farmers, resulting in no impact on the risk of pig production.

The variable of quantity of medicines did not significantly influence the risk function regression results. According to the study, because medication use was relatively uniform across farms and more reactive to disease pressure. According to O'Neill et al. (2021), recent evidence suggests that biosecurity and management practices (prevention) are far more important determinants of disease dynamics and performance than simply medication usage levels. Given the narrow variance in medication practices and the dominant role of prevention, the coefficient of "quantity of medicines" is naturally insignificant in the risk equation.

The farming model variable did not significantly influence the risk function regression results. This is because, although the breeding model has a lower risk than the combined breeding and fattening model, neither model poses a risk to the farm. This is in line with Alarcón et al. (2021) findings that the breeding model, which has a lower density and one-way workflow than the combined model, can reduce the chance of disease transmission, but has not significantly influenced the risk of pig production.

The variable of farm location in rural areas did not significantly influence the risk function regression results. Based on the research results, this is because the farm location in rural areas does not cause production risk, but rather the location of the pen behind the house. Pig farms generally build pens behind the house, so pig pens in rural areas have a lower risk, although not significantly. These results align with Bremang et al. (2022) finding that rural or suburban locales are not direct determinants of yield volatility when biosecurity standards are properly implemented.

The results of the analysis of farmers' preferences for pig production risks in Table 2 show that pig farmers are risk-averse to feed, labor and cage area and risk-takers to medicine Farmers tend not to increase the number of working hours on pig farming because pig farming is a side business from other farming businesses, namely corn and rice farming. The number of working hours for farmers is 8 hours/day, so if farmers are going to increase the number of working hours on pig farming, it will reduce the number of working hours on the family's main business. This is in line with research Delsart et al. (2020; Mbuthia et al., 2015) that farmers tend not to increase the cage area due to limited land to build cages, considering that pig pen is behind the farmer's house and adjacent to the resident's houses. Pig farming is a business that has been carried out for generations, so pig pens were built 15-20 years ago.

Furthermore, farmers tend not to increase pig feed because, currently pig farmers provide feed that exceeds the amount of pig nutritional needs. At the study site, farmers routinely provide feed ±5 kg/head/day, so their daily needs are met. Feed is given twice a day, morning and evening with an average of 2.5 kg of feed for each feeding, where this amount exceeds the feed requirements for sows (pregnant/ lactating) which range between 2-3.5 kg/day (Beyihayo et al., 2015). Farmers generally use commercial feed (i.e. complete Pokphand feed for pigs' series 551 for starters, 552 for growers and 553 for finishers). Farmers do not mix feed due to lack of corn feed and rice bran). The risk preference of pig farmers for medicine is a risk taker. If pigs are sick, they are given the antibiotic

Table 2. Pig farmers preferences for risk

| No. | Input | Risk Preference |
|---|---|---|
| 1 | Feed | Risk-averse |
| 2 | Medicine | Risk taker |
| 3 | Labour | Risk-averse |
| 4 | Cage | Risk-averse |

medoxy-la, a medicine for diarrhea in pre-starter pigs, dexaprost for pigs experiencing respiratory problems, biodin for muscle strengthening and immune system boosters, ferdex for blood boosters in pigs, to increase appetite, weight gain, and hormone metabolism. For optimal growth and reproduction processes, livestock are given vitamin b-complex and vitamin ade-plex which contain vitamins A, D3, and E. Farmers tend to add these medicines to pigs, as well as disinfectants and vaccines, considering that giving drugs is a preventative measure against pig diseases so that they do not get sick easily (Alarcón et al., 2021; Diana et al., 2017).

**Income Losses due to Production Risk**

We have previously explained factors affecting production and risk in pig production and farmer preferences for various risks faced. Next, we need to explain the extent of losses farmers face if these risks occur. There are three risks faced by farmers, outlined in the following feed prices in the total income Table 3; the risk of feed price fluctuations, the risk of pig disease, and the risk of having pig pens in residential areas.

The rise in feed costs consequently led to a notable increase in total production costs. In the breeding model, total costs increased from IDR59,493,486.35 to IDR67,379,946.60, representing a 13.26% rise. Meanwhile, in the combination model, total costs surged from IDR205,058,925.68 to IDR252,825,740.77, or approximately 23.29%. Although the cost increase was caused solely by the change in a specific input price, its effect on the overall cost structure was significant, mainly because feed contributes the largest share of total production costs, about 44% in the breeding model and 77% in the combination model.

Meanwhile, revenue from the sale of pigs and pig stock did not change between the no-risk and risk conditions, indicating that selling prices remained constant despite higher input

Table 3. The risk of increased feed prices in the total income of pig farming

| Description | No Risk Condition (IDR/period) | | 30% Increase in Input Prices (IDR/period) | |
|---|---|---|---|---|
| | Breeding Model | Breeding-Fattening Combination Model | Breeding Model | Breeding-Fattening Combination Model |
| Fixed costs | | | | |
| a. Pig pen and equipment | 10,097,142.86 | 17,330,623.54 | 10,097,142.86 | 17,330,623.54 |
| b. Breeding stock (Boar rental) | 1,887,429.00 | 1,887,429.00 | 1,887,429.00 | 1,887,429.00 |
| Subtotal | 11,984,571.86 | 19,218,052.54 | 11,984,571.86 | 19,218,052.54 |
| | | | | |
| Variable costs | | | | |
| a. Feed | 26,288,200.83 | 159,222,716.95 | 34,174,661.08 | 206,989,532.04 |
| b. Vitamins and minerals | 666,570.81 | 4,280,293.72 | 666,570.81 | 4,280,293.72 |
| c. Labour | 18,874,285.71 | 18,923,076.92 | 18,874,285.71 | 18,923,076.92 |
| d. Medicine | 679,857.14 | 914,785.55 | 679,857.14 | 914,785.55 |
| e. Electricity | 700,000.00 | 1,500,000.00 | 700,000.00 | 1,500,000.00 |
| f. Social contribution | 300,000.00 | 1,000,000.00 | 300,000.00 | 1,000,000.00 |
| Subtotal | 47,508,914.49 | 185,840,873.14 | 55,395,374.74 | 233,607,688.23 |
| Total cost | 59,493,486.35 | 205,058,925.68 | 67,379,946.60 | 252,825,740.77 |
| | | | | |
| Revenue | | | | |
| a. Sale of piglets | 34,789,714.29 | - | 34,789,714.29 | - |
| b. Sale of fattening pigs | - | 224,717,016.32 | - | 224,717,016.32 |
| c. Pig stock | 40,428,800.00 | 40,517,575.76 | 40,428,800.00 | 40,517,575.76 |
| Subtotal | 75,218,514.29 | 265,234,592.08 | 75,218,514.29 | 265,234,592.08 |
| Income (Profit/Loss) | 15,725,027.94 | 60,175,666.40 | 7,838,567.69 | 12,408,851.32 |

costs. In the breeding model, total revenue of IDR75,218,514.29 was derived from piglet sales and pig stock value, whereas in the combination model, total revenue reached IDR265,234,592.08, mainly from the sale of fattening pigs and pig stock. The imbalance between the increase in production costs and the unchanged revenue led to a sharp decline in farmers' net income.

Under the no-risk condition, the breeding model generated an income of IDR15,725,027.94/period, while the combination model produced IDR60,175,666.40. However, when the input price increased by 30%, income dropped drastically to IDR7,838,567.69 in the breeding model and IDR12,408,851.32 in the combination model. The respective decreases of 50.2% and 79.4% indicate that the combination model is much more vulnerable to input price fluctuations than the breeding model. Therefore, the breeding model is relatively more resilient to economic risks because the proportion of feed cost to total production cost is smaller.

These results suggest that under conditions of rising input prices, the breeding model remains more stable and potentially serves as a safer option for small-scale rural farmers who have limited capital and access to feed resources. In contrast, although the combination model yields higher profits under stable price conditions, it is considerably more susceptible to cost shocks resulting from input price volatility.

Based on Table 4, when the pigpens were located within residential areas or behind farmers' houses, the fixed costs increased substantially, reaching IDR32,178,857.58 for the breeding model and IDR71,209,923.16 for the breeding–fattening combination model. This increase was attributed to social risks arising from community complaints about the presence of pig farms near settlements. Consequently,

Table 4. The risk of cage location on the total income of pig farming

| Description | No Risk Condition (IDR/period) | | Cage's Location Behind the House (IDR/period) | |
|---|---|---|---|---|
| | Breeding Model | Breeding-Fattening Combination Model | Breeding Model | Breeding-Fattening Combination Model |
| Fixed costs | | | | |
| a. Pig pen and equipment | 10,097,142.86 | 17,330,623.54 | 30,291,428.58 | 69,322,494.16 |
| b. Breeding stock (Boar rental) | 1,887,429.00 | 1,887,429.00 | 1,887,429.00 | 1,887,429.00 |
| Subtotal | 11,984,571.86 | 19,218,052.54 | 32,178,857.58 | 71,209,923.16 |
| | | | | |
| Variable costs | | | | |
| a. Feed | 26,288,200.83 | 159,222,716.95 | 26,288,200.83 | 159,222,716.95 |
| b. Vitamins and minerals | 666,570.81 | 4,280,293.72 | 666,570.81 | 4,280,293.72 |
| c. Labour | 18,874,285.71 | 18,923,076.92 | 18,874,285.71 | 18,923,076.92 |
| d. Medicine | 679,857.14 | 914,785.55 | 679,857.14 | 914,785.55 |
| e. Electricity | 700,000.00 | 1,500,000.00 | 700,000.00 | 1,500,000.00 |
| f. Social contribution | 300,000.00 | 1,000,000.00 | 900,000.00 | 3,000,000.00 |
| Subtotal | 47,508,914.49 | 185,840,873.14 | 8,108,914.49 | 187,840,873.14 |
| Total cost | 59,493,486.35 | 205,058,925.68 | 80,287,772.07 | 259,050,796.30 |
| | | | | |
| Revenue | | | | |
| a. Sale of piglets | 34,789,714.29 | - | 34,789,714.29 | - |
| b. Sale of fattening pigs | - | 224,717,016.32 | - | 224,717,016.32 |
| c. Pig stock | 40,428,800.00 | 40,517,575.76 | 40,428,800.00 | 40,517,575.76 |
| Subtotal | 75,218,514.29 | 265,234,592.08 | 75,218,514.29 | 65,234,592.08 |
| Income (Profit/Loss) | 15,725,027.94 | 60,175,666.40 | (5,069,257.78) | 6,183,795.78 |

farmers were forced to relocate all their pens and equipment to a more suitable location, leading to higher investment and infrastructure adjustment costs.

For variable costs, feed remained the dominant component within the overall cost structure. In both models, feed costs amounted to IDR26,288,200.83 for the breeding model and sharply increased to IDR159,222,716.95 for the breeding–fattening combination model. Labor costs also contributed significantly, ranging from IDR18,874,285.71 to IDR18,923,076.92. Other components, such as vitamins and minerals, medicines, electricity, and social contributions, added to total expenditures, although their proportions were relatively small compared to feed and labor costs.

Overall, the highest total production cost occurred in the breeding–fattening combination model with pigpens located in residential areas that required relocation, amounting to IDR259,050,796.30. In contrast, under the no-risk condition, the lowest total cost was observed in the breeding model at IDR59,493,486.35. In terms of revenue, the combination model generated the highest income through the sale of fattening pigs, reaching IDR224,717,016.32, while the breeding model earned its primary revenue from the sale of piglets at IDR34,789,714.29.

Due to the increased fixed costs associated with the relocation of pigpens, farmers' net income declined sharply. In the breeding model, profit decreased from IDR15,725,027.94 to a loss of IDR5,069,257.78, representing a 132.2% decrease in income, indicating that the enterprise became unprofitable after relocation costs were included. Similarly, in the breeding–fattening combination model, income dropped from IDR60,175,666.40 to IDR6,183,795.78, marking an 89.7% decline. This substantial reduction illustrates that, although the combination model yields higher income under normal conditions, it is highly vulnerable to external disturbances such as forced relocation due to social conflicts in residential areas.

These findings demonstrate that the choice of production model and farm location has a significant impact on cost structure, social risk, and profitability. The breeding–fattening combination model offers greater profit potential under stable conditions but involves higher costs and more complex social risks when located in densely populated areas. Conversely, the breeding model is simpler but may suffer major losses when social disturbances require relocation. Therefore, careful planning of farm location in accordance with spatial regulations, community acceptance, and environmental policies is crucial to ensure the sustainability of pig farming in rural areas.

Table 5 shows that variable costs show a significant increase when disease strikes. Feed costs, the largest component, increased from IDR26,288,200.83 to IDR34,174,661.08 in the breeding model, and from IDR159,222,716.95 to IDR206,989,532.04 in the combined breeding-fattening model. This increase occurred because feed requirements must still be met even though some livestock experience decreased appetite or death, while the rearing period becomes longer due to slowed growth. Other cost components such as labor, vitamins, medicines, electricity, and social contributions did not show significant changes. In total, production costs increased from IDR59,493,486.35 to IDR67,379,946.60 (a 13.26% increase) in the nursery model, and from IDR205,058,925.68 to IDR252,825,740.77 (a 23.29% increase) in the combined model.

In terms of revenue, the impact of disease risk was very significant. In the nursery model, total revenue dropped drastically from IDR75,218,514.29 to only IDR54,344,685.72. This decrease was due to high piglet mortality and a decrease in the number of marketable livestock. Meanwhile, in the combined model, revenue also dropped sharply from IDR265,234,592.08 to IDR130,404,382.29, due to a decrease in production of marketable fattening pigs.

Due to the decrease in revenue and the increase in production costs, farmers experienced significant losses in net income. In the breeding model, revenue from IDR15,725,027.94 turned into a loss of IDR13,035,260.88, representing a 182.9% decrease in revenue. Meanwhile, in the combined model, revenue plummeted from IDR60,175,666.40 to a loss of IDR122,421,358.48, equivalent to a 303.4% decrease from normal conditions. This sharp decline indicates that disease risk is the most

Table 5. The disease risk on the total income of pig farming

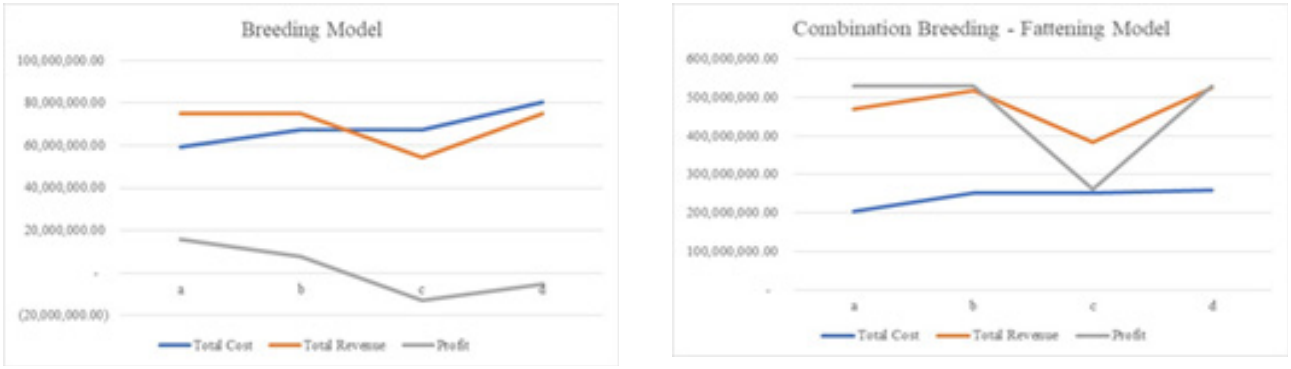
| Description | No Risk Condition (IDR/period) | | The Risk of Disease (IDR/period) | |
|---|---|---|---|---|
| | Breeding Model | Breeding-Fattening Combination Model | Breeding Model | Breeding-Fattening Combination Model |
| Fixed costs | | | | |
| a. Pig pen and equipment | 10,097,142.86 | 17,330,623.54 | 10,097,142.86 | 17,330,623.54 |
| b. Breeding stock (Boar rental) | 1,887,429.00 | 1,887,429.00 | 1,887,429.00 | 1,887,429.00 |
| Subtotal | 11,984,571.86 | 19,218,052.54 | 11,984,571.86 | 19,218,052.54 |
| | | | | |
| Variable costs | | | | |
| a. Feed | 26,288,200.83 | 159,222,716.95 | 34,174,661.08 | 206,989,532.04 |
| b. Vitamins and minerals | 666,570.81 | 4,280,293.72 | 666,570.81 | 4,280,293.72 |
| c. Labour | 18,874,285.71 | 18,923,076.92 | 18,874,285.71 | 18,923,076.92 |
| d. Medicine | 679,857.14 | 914,785.55 | 679,857.14 | 914,785.55 |
| e. Electricity | 700,000.00 | 1,500,000.00 | 700,000.00 | 1,500,000.00 |
| f. Social contribution | 300,000.00 | 1,000,000.00 | 300,000.00 | 1,000,000.00 |
| Subtotal | 47,508,914.49 | 185,840,873.14 | 55,395,374.74 | 233,607,688.23 |
| Total cost | 59,493,486.35 | 205,058,925.68 | 67,379,946.60 | 252,825,740.77 |
| | | | | |
| Revenue | | | | |
| a. Sale of piglets | 34,789,714.29 | - | 13,915,885.72 | - |
| b. Sale of fattening pigs | - | 224,717,016.32 | - | 89,886,806.53 |
| c. Pig stock | 40,428,800.00 | 40,517,575.76 | 40,428,800.00 | 40,517,575.76 |
| Subtotal | 75,218,514.29 | 265,234,592.08 | 54,344,685.72 | 130,404,382.29 |
| Income (Profit/Loss) | 15,725,027.94 | 60,175,666.40 | (13,035,260.88) | (122,421,358.48) |

serious threat to the sustainability of pig farming businesses, as it not only reduces productivity but can also result in significant financial losses.

Overall, these results indicate that both the breeding and combined models are highly susceptible to disease risks, with losses far exceeding profit margins under normal conditions. Therefore, implementing strict livestock health management, routine vaccination, and a sound biosecurity system are crucial steps to mitigate the economic impact of disease outbreaks on pig farms in rural areas.

All the figures presented in Tables 3, 4, and 5, when visualized in graphical form, clearly illustrate the comparison between the no-risk condition and the various types of risks in pig farming. Figure 1 presents the visualization of these three tables, where part (a) shows the no-risk condition, part (b) illustrates the feed price risk, part (c) represents the disease risk, and part (d) depicts the pigpen location risk. Through Figure 1, the trends in changes in costs, revenues, and farmers' income under each risk condition compared to the normal (no-risk) condition can be observed more clearly.

Overall, the findings demonstrate that the breeding–fattening combination model yields higher production but carries significantly greater risk compared to the breeding model. Despite these risks, farmers continue to produce pigs, showing strong resilience. However, ensuring the sustainability of smallholder pig farming requires targeted interventions, including feed price stabilization, disease prevention and control, and improved environmental management through waste treatment technologies such as biogas. In addition, government support in stabilizing the market price of pigs is crucial, as farmer income is highly sensitive to fluctuations in selling prices (Pourmoayed et al., 2022).




(A) (B)

Information: a (when there is no risk), b (there is a risk of feed), c (there is a risk of disease), and d (there is a risk of cage)

Figure 1. Benefits received by pig farmers for breeding model (A) and combination model of breeding-fattening in pig farming (B).

Overall, the findings demonstrate that the breeding–fattening combination model yields higher production but carries significantly greater risk compared to the breeding model. Despite these risks, farmers continue to produce pigs, showing strong resilience. However, ensuring the sustainability of smallholder pig farming requires targeted interventions, including feed price stabilization, disease prevention and control, and improved environmental management through waste treatment technologies such as biogas. In addition, government support in stabilizing the market price of pigs is crucial, as farmer income is highly sensitive to fluctuations in selling prices (Pourmoayed et al., 2022).

**Farmer Strategies to Manage Production Risk**

Pig farmers need to have a strategy for dealing with the risks of pig production that is adjusted to the potential and local culture of the local area. Strategy is a short-term effort that pig farmers must make to overcome direct threats to pig production, namely the risk of feed and disease. Some strategies are: (1) Diversifying businesses: namely in addition to pig production in pig farming, pig farmers also work on other farming businesses to reduce dependence on one source of income. Corn is one source of pig feed whose price fluctuates, so corn production in corn farming is a suitable farming business to be worked on together with pig farming. Thus, the expenditure on corn feed for pig production can be reduced; (2) To implement good financial management, pig farmers must provide reserve funds to face difficult times in pig production. This activity can be done in groups as a pig farming community; (3) Implementing biosecurity to prevent pigs from being attacked by disease outbreaks. Since ASF attacked pigs, some pig farmers have implemented biosecurity in pig production. Among other things, controlling visitors who enter and providing a place to wash their feet (Anh et al., 2023; Callegari et al., 2020).

## CONCLUSIONS

At the rural areas of North Sulawesi, the breeding model resulted in higher production than the combined breeding-fattening pig farming model and tends to have lower production risks, particularly disease-related risks that directly affect productivity and farm continuity. This risk identification indicates that the more dynamic the production system, the greater the uncertainty farmers must face. These risks significantly reduce household production and income, highlighting the strong relationship between production dynamics, risk levels, and the economic stability of rural pig farmers.

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## REFERENCES


Alarcón, L. V., Allepuz, A., & Mateu, E. (2021). Biosecurity in pig farms: a review. *Porcine Health Management*, 7(1). https://doi.org/10.1186/s40813-020-00181-z

Anh, H. H., Na, L., Thuy, N. N., Beaulieu, A., & Hanh, T. M. D. (2023). Knowledge, attitude, and practices of swine farmers related to livestock biosecurity: a case study of African swine fever in Vietnam. *Journal of Agricultural Sciences - Sri Lanka*, 18(3). https://doi.org/10.4038

Beyihayo, G., Mwesigwa, R., & Pezo, D. (2015). Pig feeding strategies: Uganda smallholder pig value chain capacity development training manual. *International Livestock Research Institute* (ILRI).

Bremang, A., Ho, J., Conan, A., Tang, H., Oh, Y., & Pfeiffer, D. (2022). Guidelines for African swine fever (ASF) prevention and control in smallholder pig farming in Asia. In Guidelines for African swine fever (ASF) prevention and control in smallholder pig farming in Asia. *FAO.* https://doi.org/10.4060/cb9187en

Callegari, M. A., Pierozan, C. R., Dias, C. P., De Souza, K. L., Foppa, L., Gasa, J., & Da Silva, C. A. (2020). Brazilian panorama of pig breeding sector: A cross-sectional study about specific aspects of biosecurity, facilities, management, feeding, and performance. Semina: *Ciencias Agrarias*, 41(2). https://doi.org/10.5433

Chah, J., Nwobodo, C., Utaka, M., & Asadu, A. (2016). Pig health management strategies among farmers in Enugu State, Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology*, 10(3). https://doi.org/10.9734/ajaees/2016/24934

Delsart, M., Pol, F., Dufour, B., Rose, N., & Fablet, C. (2020). Pig farming in alternative systems: Strengths and challenges in terms of animal welfare, biosecurity, animal health and pork safety. *Agriculture*, 10(7). https://doi.org/10.3390/agriculture10070261

Diana, A., Manzanilla, E. G., Calderón Díaz, J. A., Leonard, F. C., & Boyle, L. A. (2017). Do weaner pigs need in-feed antibiotics to ensure good health and welfare. *Plos one*, 12(10). https://doi.org/10.1371/journal.pone.0185622

Erdyana, E., & Rum, Mokh. (2021). Analisis risiko dan kelayakan finansial peternakan ayam broiler dengan pola kemitraan (studi kasus peternakan bapak Wawan di Kecamatan Pilangkenceng, Kabupaten Madiun). *Agriscience*, 2(1). https://doi.org/10.21107

Fakihuddin, F., Suhariyanto, T. T., & Faishal, M. (2020). Analisis dampak lingkungan dan persepsi masyarakat terhadap industri peternakan ayam (studi kasus pada peternakan di Jawa Tengah). *Jurnal Teknik Industri*, 10(2), 191-199. https://doi.org/10.25105

Gregolin, F., & Miranda, K. O. D. S. (2023). Risk management in pig farming: a reality or conjecture? A systematic review. *Animal Production Science*, 63(13), 1261-1271. https://doi.org/10.1071/AN22468

Gujarati, D. N., & Porter, D. C. (2013). *Basic Econometrics*. introductory econometrics: a practical approach. McGraw-Hill.

Li, S., Ma, H., Wu, J., Lu, J., Qiao, S., Zeng, X., & Zhou, J. (2025). Dietary digestible protein requirement in finishing pigs: A study for experimental determination and verification. *Agriculture*, 15(12). https://doi.org/10.3390/agriculture15121306

Manese, M. A. V., Santa, N. M., & Bukanaung, E. P. (2021). Contribution of pig farming to households in Tenga Subdistrict, South Minahasa District. *IOP Conference Series: Earth and Environmental Science,* 892(1). https://doi.org/10.1088/1755-1315/892/1/012016

Manevska-Tasevska, G., Hansson, H., & Labajova, K. (2017). Impact of management practices on persistent and residual technical efficiency – A study of Swedish pig farming. *Managerial and Decision Economics*, 38(6). https://doi.org/10.1002/mde.2823

Mappa, N., Rahmawati, R., & Nurfadillah, N. (2022). Analisis resiko usaha ayam potong mandiri dan alternatif penanggulangannya. *AgriMu*, 2(1). https://doi.org/10.26618

Marani, O., Santoso, B., & Pattiselanno, F. (2023). Produksi gas buangan ternak babi yang diumbar di Gaya Baru dan sekitar Pasar Wosi, Manokwari. *Dinamika*

*Lingkungan Indonesia*, 10(1). https://doi.org/10.31258/dli.10.1.p.19-28

Marchant-Forde, J. N., & Boyle, L. A. (2020). Covid-19 effects on livestock production: A one welfare issue. *Frontiers in Veterinary Science*, 7. https://doi.org/10.3389/fvets.2020.585787

Mbuthia, J. M., Rewe, T. O., & Kahi, A. K. (2015). Evaluation of pig production practices, constraints and opportunities for improvement in smallholder production systems in Kenya. *Tropical Animal Health and Production,* 47(2). https://doi.org/10.1007/s11250-014-0730-2

Meyer-Hamme, S. E. K., Lambertz, C., & Gauly, M. (2016). Does group size have an impact on welfare indicators in fattening pigs? *Animal*, 10(1). https://doi.org/10.1017/S1751731115001779

Ocepek, M., & Andersen, I. L. (2022). The effects of pen size and design, bedding, rooting material and ambient factors on pen and pig cleanliness and air quality in fattening pig houses. *Animals*, 12(12). https://doi.org/10.3390/ani12121580

O'Neill, L., Calderón Díaz, J. A., Rodrigues da Costa, M., Oakes, S., Leonard, F. C., & Manzanilla, E. G. (2021). Risk factors for antimicrobial use on Irish pig farms. *Animals*, 11(10). https://doi.org/10.3390/ani11102828

Peplinski, B. (2020). Location of cows and pigs in suburban areas of polish metropolitan centers. *Sustainability*, 12(7). https://doi.org/10.3390/su12072619

Pietrosemoli, S., & Tang, C. (2020). Animal welfare and production challenges associated with pasture pig systems: A review. *Agriculture*, 10(6). https://doi.org/10.3390/agriculture10060223

Pourmoayed, R., & Relund Nielsen, L. (2022). Optimizing pig marketing decisions under price fluctuations. *Annals of Operations Research*, 314(2). https://doi.org/10.1007/s10479-020-03646-0

Santa, N. M., Manese, M. A. V., & Waleleng, P. O. V. (2021). The efficiency of pig farming inputs in Minahasa Regency of North Sulawesi. *Journal of the Indonesian Tropical Animal Agriculture,* 46(1). https://doi.org/10.14710/JITAA.46.1.84-90

Santa, N. M., & Wantasen, E. (2018). Profit analysis of pig farming in rural comunities in Minahasa Regency of North Sulawesi. *Journal of the Indonesian Tropical Animal Agriculture*, 43(3), 289–295. https://doi.org/10.14710/jitaa.43.3.289-295

Sinurat, M. (2019). Analysis of influenced factors the reduction of pig population in Simanindo District, Samosir Regency. *Jurnal Peternakan Integratif*, 7(3). https://doi.org/10.32734

Soltész, A., Szőke, S., & Balogh, P. (2014). Analysis of economic risks in sow production. *Journal of Agricultural Informatics*, 4(2). https://doi.org/10.17700/jai.2013.4.2.114

Sugiyono. (2020). *Metodologi Penelitian Kuantitatif, Kualitatif dan r & d. Alfabeta.*

Tembei, M. L., Ernest L. Molua, & Ajapnwa Akamin. (2019). Production risk and risk preference among small-scale pig enterprises in Southwestern Cameroon. *6th African Conference of Agricultural Economists*, Abuja, Nigeria.

Thanapongtharm, W., Linard, C., Chinson, P., Kasemsuwan, S., Visser, M., Gaughan, A. E., Epprech, M., Robinson, T. P., & Gilbert, M. (2016). Spatial analysis and characteristics of pig farming in Thailand. *Veterinary Research*, 12(1). https://doi.org/10.1186/s12917-016-0849-7

Thoma, G. J., Baker, B., & Knap, P. W. (2024). A life cycle assessment study of the impacts of pig breeding on the environmental sustainability of pig production. *Animals*, 14(16). https://doi.org/10.3390/ani14162435

Tian, X., Sun, F. fei, & Zhou, Y. heng. (2015). Technical efficiency and its determinants in China's hog production. *Journal of Integrative Agriculture,* 14(6). https://doi.org/10.1016/S2095-3119(14)60989-8

Trabachini, A., Moreira, M. da R., Harada, É. D. S., Amorim, M. do N., & Silva-Miranda, K. O. da. (2025). Precision livestock farming applied to Swine farms-a systematic literature review. *Animals*, 15(14). https://doi.org/10.3390/ani15142138

Viltrop, A., Boinas, F., Depner, K., Jori, F., Kolbasov, D., Laddomada, A., & Ståhl, K. (2021). African swine fever epidemiology, surveillance and

control. *Understanding and combatting African Swine Fever*, (9). https://doi.org/10.3920/978-90-8686-910-7

Vinanda, G., Harianto, H., & Anggraeni, L. (2016). Resiko produksi ayam broiler dan preferensi peternak di Kabupaten Bekasi. *Jurnal Manajemen Dan Agribisnis,* 13(1). https://doi.org/10.17358/jma.13.1.50

White, B. (2012). Agriculture and the generation problem: rural youth, employment and the future of farming. *IDS Bulletin*, 43(6). https://doi.org/10.1111/j.1759-5436.2012.00375.x

Woran, J., Mulyadi, M., Keworip, L., Pakage, S., Saragih, D., Sagrim, M., Orisu, L., & Iyai, D. A. (2020). The contribution of labors to the income of pig farming business in the Tropical Coastal Papua Barat. *Buletin Peternakan*, 44(1). https://doi.org/10.21059

Yan, Z., Wang, C., Xu, J., Huo, X., & Hussain, Q. (2019). Examining the effect of absorptive capacity on waste processing method adoption: a case study on Chinese pig farms. *Journal of Cleaner Production,* 215. https://doi.org/10.1016/j.jclepro.2019.01.09