Research Article

Integrated Economic Viability and Sustainability Assessment of Dry Litter Duck Farming Among Smallholders in Pinrang Regency, South Sulawesi

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Abstract | Dry-litter duck farming has become increasingly adopted by smallholder producers in Indonesia, yet empirical assessments integrating economic feasibility and sustainability remain limited particularly in Pinrang Regency, a major duck-egg production center in South Sulawesi. This study evaluates the economic viability and economic sustainability of smallholder dry-litter duck farming through an integrated analytical framework. A total of 53 farmers implementing the dry-litter system were purposively selected in 2025. Data were collected through structured questionnaires, production measurements, and field observations. Economic viability was analyzed using cost structure, revenue, income, and the Benefit–Cost (B/C) ratio. Economic sustainability was assessed using Multi-Dimensional Scaling (MDS) across nine attributes, complemented by leverage and Monte Carlo analysis. All farm scales demonstrated economic feasibility (B/C > 1). The 500 duck scale achieved the highest profitability (B/C= 1.64), while income increased consistently with expansion, reaching IDR 279,564,583 at the 2,000-duck scale. The economic sustainability index was 74.54%, categorized as moderately sustainable. Key attributes influencing sustainability were farm-scale expansion, product diversification, and output market access. These findings confirm that duck farming with a dry-litter housing system in Pinrang Regency is not only economically feasible across all production scales but also demonstrates moderate economic sustainability. The integration of feasibility and sustainability analyses provides empirical evidence that medium-scale operations offer optimal profitability, while long-term resilience is largely determined by scale dynamics, product diversification, and market access. These findings contribute to the limited literature on integrated economic–sustainability assessments of duck production systems in Indonesia and offer practical insights for policy formulation and smallholder development strategies.

Keywords | Dry-litter duck farming, Economic feasibility, Economic sustainability, Multi-Dimensional Scaling (MDS), Smallholder farmers

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INTRODUCTION

The livestock subsector plays a crucial role in national food systems by supplying animal protein and supporting rural livelihoods, with demand continuing to increase due to population growth, rising incomes, and shifting dietary preferences toward animal-based foods (Birhanu *et al.*, 2023). Within this subsector, poultry

provides the largest contribution, and duck farming occupies a strategic position, particularly through egg production with relatively high economic value. In Indonesia, the duck population increased from 33.4 million to 43.5 million birds in 2024 (Statistics Indonesia, 2025), indicating strong development potential. Ducks are also known for their adaptability and competitive productivity, averaging 200–240 eggs per bird per year (Bagau *et al*., 2018), which supports their role in sustainable agribusiness development (Juwita *et al*., 2024).

As duck farming expands, the dry-litter housing system has been increasingly adopted due to its higher efficiency compared with wetland-based systems. This system enables better environmental control, improved sanitation, reduced disease risk, and more stable year-round production, making it suitable for areas facing land constraints and agricultural intensification. However, its successful implementation depends heavily on feed management, capital availability, and technological support, underscoring the need for comprehensive economic assessment (Santoso *et al*., 2025).

Pinrang Regency in South Sulawesi Province is one of the major centers of duck farming in Indonesia, dominated by smallholder production systems. The region benefits from favorable conditions, including the availability of local feed resources and access to regional egg markets. Nevertheless, farmers face challenges such as rising feed costs, egg price fluctuations, and the decline of post-harvest grazing due to changes in cropping patterns, pesticide use, and land conversion. These constraints have accelerated the transition toward dry-litter systems as a more stable and controllable production alternative (Jha *et al*., 2017).

Previous studies on duck farming in Pinrang Regency have largely focused on general enterprise development and basic feasibility analysis. For example, Hastang *et al*. (2021) evaluated overall development without differentiating production systems or integrating comprehensive economic indicators. To date, no study has specifically examined both the economic feasibility and economic sustainability of dry-litter duck farming systems, despite their increasing adoption and perceived economic advantages.

In the context of sustainable poultry development, business success depends not only on short-term profitability but also on the capacity to remain resilient under market fluctuations, feed price volatility, and production risks. Factors such as cost efficiency, scale of operation, productivity, product diversification, access to capital, technology adoption, and market networks play a critical role in shaping economic sustainability (Bist *et al*., 2024). Accordingly, this study aims to analyze the economic feasibility and assess the level of economic sustainability of dry-litter duck farming systems operated by smallholder farmers in Pinrang Regency. The study integrates cost–income analysis, the Benefit–Cost (B/C) ratio, and Multi-Dimensional Scaling (MDS) across nine economic sustainability attributes, offering an integrated evaluation framework and strategic insights to strengthen the long-term economic resilience of smallholder duck farmers.

MATERIALS AND METHODS

Research area and period

This study was conducted in Pinrang Regency, South Sulawesi, from March to August 2025. The study area was purposively selected because Pinrang is one of the major centers of laying duck production in South Sulawesi, with a high concentration of farmers adopting the dry-litter housing system and a wide range of production scales that allow for a comprehensive evaluation of economic feasibility and sustainability.

Type of research

This study employed a quantitative approach with an explanatory survey design aimed at explaining the relationships among production variables, cost structure, income, and economic sustainability indicators in dry-litter duck farming. This approach was selected to obtain a measurable empirical overview of the efficiency and economic resilience of farmers' enterprises across different production scales.

Population and sample

The study population consisted of all duck farmers applying the dry-litter system in Pinrang Regency. The sampling technique employed was purposive sampling, with the following criteria: (1) actively operating a duck farming enterprise for ≥1 year, (2) fully implementing the dry-litter housing system, and (3) willing to participate as respondents. The total sample consisted of 53 farmers.

Types and sources of data

This study employed a combination of primary and secondary data to obtain a comprehensive overview of the economic feasibility and sustainability of dry-litter duck farming in Pinrang Regency. Primary data included information on production cost structure, revenue components, duck productivity, the use of feed and labor inputs, selling prices, managerial dynamics, and farmers' assessments of economic dimension attributes, all collected directly from respondents. Meanwhile, secondary data were obtained from relevant institutions such as the Pinrang Livestock Office, Statistics Indonesia, previous research reports related to duck husbandry systems, financial feasibility analysis, and economic sustainability studies in the poultry sector.

Data were collected through:

1. Structured surveys using closed and semi-open questionnaires administered to sampled farmers to gather information on production, variable and fixed costs, farm scale, income, and respondents' assessments of the economic dimension.
2. Direct field measurements of selected production input–output components to increase data accuracy.
3. Participatory observation of housing conditions, feed management, and daily farm operations.
4. Documentation of available production records and historical farm data.

MATERIALS AND METHODS

Descriptive economic analysis

The economic analysis focused on formulas and relevant references, as follows:

Cost structure

Total cost (TC) was calculated as the sum of fixed costs (FC) and variable costs (VC) (Barus *et al*., 2024):

$$TC = FC+VC$$

Where; TC: Total Cost; FC: Total Fixed Cost; VC: Total Variabel Cost.

Total revenue

Total revenue was obtained by multiplying the quantity of output (Q) by the selling price per unit (P) (Subiarto *et al*., 2022):

$$\text{Total Revenue} = P \times Q$$

Where; P: Price (selling price per unit), Q: Quantity (total production

Net income

Net income was calculated as the difference between total revenue and total cost (Nurlaelah *et al*., 2022):

$$\text{Net Income} = TR - TC$$

Where; TR: Total Revenue, TC: Total Cost.

Benefit-cost (B/C) ratio

Profitability was measured using the B/C ratio (Sheheli *et al*., 2023):

$$B/C = \frac{TR}{TC}$$

Where; TR: Total Revenue, TC: Total Cost, An enterprise was considered economically viable when B/C > 1.

Multidimensional scalling (MDS) analysis

The sustainability analysis in this study was conducted using the Multi-Dimensional Scaling (MDS) approach, which has been widely applied in sustainability assessments within the livestock, fisheries, and agricultural sectors. MDS functions to map the sustainability position of a production system based on attribute scores representing each dimension, namely the economic, social, and environmental dimensions (Hardi and Soedarto, 2023).

This study applied Multi-Dimensional Scaling (MDS) to assess economic sustainability using a structured scoring system across nine economic attributes. A total of nine attributes were included: income, input access, output access, capital availability, marketing reach, farm-scale dynamics, productivity, product diversification, and price stability. Each attribute was scored using ordinal scale of 0-3, where:

- 0 = Very Poor
- 1 = Poor
- 2 = Good
- 3 = Very Good

Analysis was conducted using MDS Phyton, applying RAPFISH-based MDS procedures for ordination, leverage, and Monte Carlo simulation. The sustainability index is classified into four categories (Table 1), as follows:

Table 1: Sustainability index classification.

Sustainability Index	Category
0.00 – 25.00	Not sustainable
25.01 – 50.00	Less sustainable
50.01 – 75.00	Moderately sustainable
75.01 – 100.00	Sustainable

Source: (Handayani *et al*., 2023).

In addition to generating an index, the MDS analysis also produces stress values and the coefficient of determination (R^2) to assess the quality and reliability of the model. A lower stress value indicates that the MDS configuration accurately represents the attribute positions, while an R^2 value approaching 1 signifies that the model explains data variation optimally. In sustainability studies, satisfactory stress values are typically below 0.25 and R^2 values exceed 0.90, indicating that the results are stable and reliable (Mahida and Handayani, 2019).

To identify the most influential attributes in determining the sustainability index, a leverage analysis was conducted, which evaluates sensitivity through the measurement of changes in the Root Mean Square (RMS) of each attribute (Pawiengla *et al*., 2020). Attributes with the highest RMS changes are considered key determinants contributing most significantly to increases or decreases

in system sustainability. Leverage results form the basis for recommending priority improvements and policy interventions for each dimension.

A Monte Carlo analysis was then performed to evaluate the effects of uncertainty in the scoring and data processing stages. The Monte Carlo simulation was conducted repeatedly at a 95% confidence level to compare the MDS index with the simulation results. Small differences between the two indicate that the attribute scoring process is stable, free from significant bias, and not strongly affected by random errors or respondent inconsistency.

RESULTS AND DISCUSSION

Characteristics of dry litter duck farming systems

Duck farming enterprises applying the dry-litter housing system in Pinrang Regency were managed by farmers aged 24–65 years, with the majority falling within the productive age group of 36–41 years. Most farmers held a bachelor's degree, indicating a relatively high educational background. However, their experience in managing duck farming operations was generally limited, averaging 1–2 years.

The production system began with laying-ready ducks aged approximately five months and was operated for about six months. Ducks were reared intensively in enclosed housing, where feeding, watering, and daily monitoring were conducted entirely indoors. The housing floor consisted of dry litter material functioning as a moisture-absorbing layer. Pens were divided into sections to facilitate grouping based on age and performance, and the houses were equipped with adequate ventilation to maintain air quality and reduce humidity.

Feed and water were provided inside the housing, with an average feed requirement of 0.12 kg/duck/day using complete feed or locally formulated rations. Feeders were placed at elevated positions to prevent litter moisture, while drinking water was supplied through nipple drinkers or circular pipe systems to ensure even distribution and maintain litter dryness. Litter management involved daily leveling and annual removal of litter mixed with feces.

Cost structure, revenue and income of dry litter duck farming

Income analysis is a fundamental stage in assessing the financial feasibility and economic efficiency of dry-litter duck farming. The cost structure of dry-litter duck farming enterprises in Pinrang Regency consisted of fixed and variable costs (Table 2). Variable costs increased markedly with farm scale, from IDR 29,261,040 at 120 ducks to IDR 465,700,000 at 2,000 ducks. In contrast, fixed costs showed greater variability, ranging from IDR 10,031,250 to IDR 63,533,750, reflecting differences in investment intensity and facility utilization among farms.

Table 2: Costs per production period in dry litter duck farming systems.

No.	Farm scale (Heads)	Fixed Costs/ Period (IDR)	Variable costs/ Period (IDR)
1	120	10,031,250	29,261,040
2	150	10,451,250	34,883,800
3	300	14,012,333	69,845,600
4	500	10,459,583	119,821,000
5	650	35,887,083	146,450,000
6	700	36,003,333	160,127,200
7	800	32,258,333	178,679,400
8	900	36,991,042	219,705,000
9	1300	63,533,750	307,920,000
10	1500	62,805,000	395,887,200
11	1700	40,851,000	414,460,000
12	2000	41,746,250	465,700,000

Table 3: Total revenue per production period in dry-litter duck farming systems.

No	Farm scale (Heads)	Egg revenue (IDR)	Culled Duck revenue (IDR)	Manure revenue (IDR)	Final flock value (IDR)	Total revenue (IDR)
1	120	44,349,000	5,780,000	300,000	1,500,000	51,929,000
2	150	50,360,000	5,720,000	150,000	3,360,000	59,590,000
3	300	95,915,000	12,025,000	450,000	6,300,000	114,690,000
4	500	182,500,000	11,570,000	540,000	19,020,000	213,630,000
5	650	195,361,500	14,300,000	300,000	25,200,000	235,161,500
6	700	245,705,600	33,930,000	330,000	8,880,000	288,845,600
7	800	281,225,000	25,350,000	450,000	23,700,000	330,725,000
8	900	320,868,000	32,700,000	1,200,000	18,300,000	373,068,000
9	1300	458,100,000	61,100,000	810,000	19,800,000	539,810,000
10	1500	552,517,700	69,875,000	900,000	23,940,000	647,232,700
11	1700	559,150,000	65,800,000	990,000	43,800,000	709,740,000
12	2000	657,580,833	83,980,000	750,000	44,700,000	787,010,833

Total revenue increased consistently with farm scale (Table 3), rising from IDR 51,929,000 at 120 ducks to IDR 787,010,833 at 2,000 ducks. Egg sales constituted the dominant source of revenue across all scales, while cull ducks, feces, and terminal livestock value provided additional, though smaller, contributions.

Net income followed an overall increasing trend with scale (Table 4). Net income ranged from IDR 12,636,710 at 120 ducks to IDR 279,564,583 at 2,000 ducks, although income fluctuations were observed at intermediate scales (650–900 ducks).

Table 4: Total income per production period in dry-litter duck farming systems.

No.	Farm scale (Heads)	Total costs/ period (IDR)	Total revenue/ period (IDR)	Total income/ Period (IDR)
1	120	39,292,290	51,929,000	12,636,710
2	150	45,335,050	59,590,000	14,254,950
3	300	83,857,933	114,690,000	30,832,067
4	500	130,280,583	213,630,000	83,349,417
5	650	182,337,083	235,161,500	52,824,417
6	700	196,130,533	288,845,600	92,715,067
7	800	210,937,733	330,725,000	119,787,267
8	900	256,696,042	373,068,000	116,371,958
9	1300	371,453,750	539,810,000	168,356,250
10	1500	458,692,200	647,232,700	188,540,500
11	1700	455,311,000	709,740,000	254,429,000
12	2000	507,446,250	787,010,833	279,564,583

Feasibility and dry-litter duck farming

The benefit–cost (B/C) ratio for all production scales exceeded 1 (Table 5), indicating that dry-litter duck farming was economically feasible across all observed scales. The highest B/C ratio (1.64) was recorded at the 500-duck scale.

Table 5: Feasibility analysis of duck farming using a dry-litter management system.

No	Farm Scale (Heads)	B/C Ratio
1	120	1.32
2	150	1.31
3	300	1.37
4	500	1.64
5	650	1.29
6	700	1.47
7	800	1.57
8	900	1.45
9	1300	1.45
10	1500	1.41
11	1700	1.56
12	2000	1.55

Economic sustainability analysis of dry-litter duck farming

To further deepen the analysis of economic feasibility, a Multidimensional Scaling (MDS) mapping was conducted on nine economic dimension attributes of duck farming, namely: (1) farm income; (2) input market access; (3) output market access; (4) capital used in the enterprise; (5) marketing reach; (6) changes in farm scale; (7) duck productivity level; (8) product diversification; and (9) price stability.

The Multidimensional Scaling (MDS) analysis of the economic dimension yielded a sustainability index of 74.54%, indicating a moderately sustainable status within the 50.01–75.00% interval. The ordination plot (Figure 1) showed that the farming units were positioned in the right quadrant and tended toward the good sustainability region. Sustainability scores ranged from 60 to 90, suggesting relatively stable economic performance of dry-litter duck farming enterprises in Pinrang Regency.

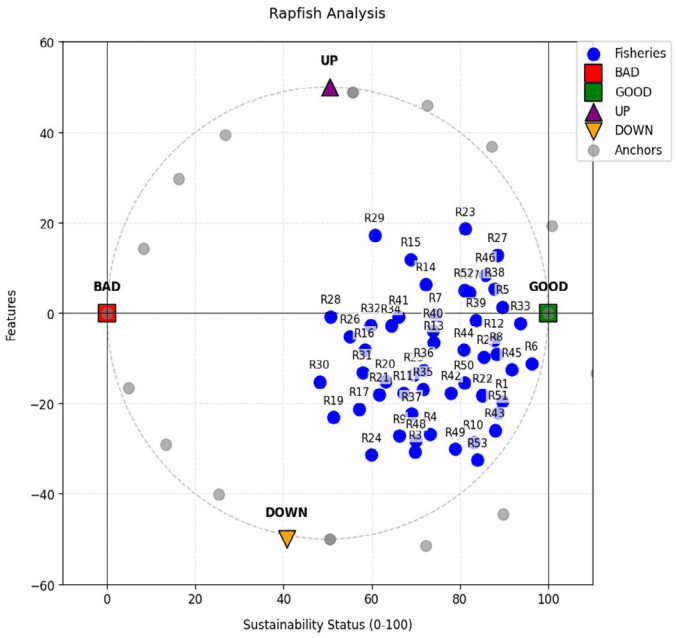

Figure 1: Ordination of the economic dimension.

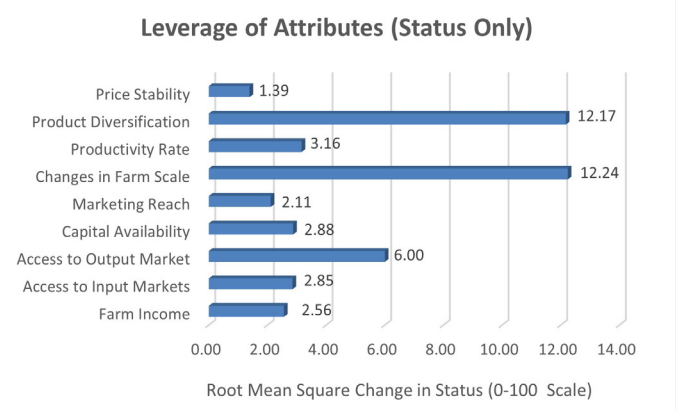

Figure 2: Leverage attributes of the economic dimension.

Leverage analysis identified key economic attributes influencing sustainability (Figure 2). The most sensitive attributes, based on Root Mean Square (RMS) values, were change in production scale (12.24), product diversification (12.17), and output market access (6.00). Attributes with moderate sensitivity included duck productivity (3.16), capital availability (2.88), and input market access (2.86). Attributes with lower sensitivity were farm income (2.56), marketing range (2.11), and price stability (1.39).

DISCUSSION

The predominance of farmers within the productive age group and their relatively high educational attainment suggest favorable human capital for adopting and managing dry-litter housing systems. Higher education levels are commonly associated with improved capacity to implement technological innovations and apply sound management practices in livestock production systems.

Despite this advantage, the short duration of farming experience indicates that the dry-litter system is a relatively recent innovation in the study area. Limited experience may constrain farmers' ability to optimize operational efficiency and respond effectively to production challenges. Previous studies have shown that farming experience plays a critical role in enhancing problem identification, decision-making, and the adoption of science-based livestock management practices (Das *et al*., 2020).

The observed housing design, feeding strategy, and litter management practices reflect key technical features of dry-litter systems aimed at controlling moisture, maintaining hygiene, and reducing disease risk. Proper ventilation, elevated feeders, and controlled watering systems are essential to maintaining litter quality, which directly affects bird health and productivity. Consistent litter management practices observed in this study support the potential of dry-litter housing to improve environmental conditions within duck production systems when appropriately managed.

The sharp increase in variable costs with expanding production scale highlights feed and operational inputs as the primary cost drivers in dry-litter duck farming systems. In contrast, the relatively stable and fluctuating pattern of fixed costs suggests that capital investments are largely determined by individual farmers' infrastructure capacity and investment strategies, rather than by scale alone. Similar cost behavior patterns have been reported in livestock production systems where variable inputs dominate total production costs (Karaman *et al*., 2023).

The strong positive relationship between farm scale and total revenue was mainly driven by egg production, confirming eggs as the principal income source in duck farming enterprises. This finding aligns with previous studies indicating that larger production scales enhance output volume and gross revenue potential (Houedjofonon *et al*., 2020). Supplemental income from cull ducks, feces, and terminal livestock value, although relatively small, contributed to income diversification and improved overall revenue stability (Pangemanan *et al*., 2014).

The observed increase in net income with scale indicates that expanding production generally improves profitability. However, income variability at intermediate scales suggests that scale expansion alone does not guarantee higher profits. Efficient cost control and operational management remain critical, particularly at medium-scale operations, before reaching an optimal scale of production (Thobe and Haxsen, 2014).

The consistently positive B/C ratios across all scales confirm the economic feasibility of dry-litter duck farming systems. The highest B/C ratio at the 500-duck scale suggests that medium-scale operations may achieve a more favorable balance between cost efficiency and revenue generation. This scale allows farmers to benefit from increased production output while maintaining manageable cost growth, supporting previous findings that medium-scale livestock enterprises often provide optimal economic performance (Islam *et al*., 2024; Priyanto *et al*., 2025).

The dominance of production scale change as the most sensitive attribute indicates that capacity expansion plays a critical role in enhancing economic sustainability. Despite farm sizes ranging from 120 to 2,000 ducks, the observed scale increase since establishment was marginal, reflecting constraints related to limited capital, feed price volatility, and mortality risk. Similar findings have emphasized the importance of strategic investment to enable sustainable livestock expansion through improved resource efficiency and system resilience (Enahoro *et al*., 2019).

Product diversification emerged as a key leverage attribute, highlighting farmers' limited ability to generate value-added products. The current production portfolio was largely restricted to table eggs, hatching eggs, live cull ducks, and limited composted manure. The absence of processed products, such as salted eggs, meat-based products, or commercially processed waste, increased income dependency on raw egg prices, thereby elevating economic risk. Product diversification has been widely recognized as a strategy to enhance economic value, nutritional quality, and shelf life of duck products (Kusmayadi and Sundari, 2019).

Output market access also played a significant role in determining sustainability. Marketing activities were primarily confined to local and regional markets within South Sulawesi, including Pinrang, Sidrap, Makassar, and Gowa. Limited market reach may restrict farmers' ability to obtain competitive prices, as market access, competition, and transaction costs strongly influence farm income performance (Magakwe, 2024).

Moderately sensitive attributes, such as productivity, capital, and input access, reflected relatively stable farm management conditions. Egg productivity levels of 70–75% indicated consistent performance under the dry-litter system, supported by adequate feeding, health management, and housing conditions. Stable productivity contributes to risk mitigation and long-term farm sustainability (Otunaiya, 2023). However, reliance on personal capital without formal credit limited farmers' capacity for expansion, as independently financed farms often face restricted access to production inputs and growth opportunities (Lestari *et al*., 2024).

Attributes with lower sensitivity, including income level, marketing range, and price stability, suggested that short-term income fluctuations were less influential on sustainability compared with structural factors such as scale and diversification. Although egg prices were seasonal, their fluctuations were relatively predictable and influenced by supply–demand dynamics and market integration across regions (Jojo *et al*., 2021).

CONCLUSION

This study confirms that dry-litter duck farming in Pinrang Regency is economically feasible and moderately sustainable. All production scales achieved B/C ratios above one, indicating positive financial performance, with the highest economic efficiency observed at the medium scale (around 500 ducks). The economic sustainability index of 74.54% further supports the viability of this production system. Multidimensional Scaling analysis identified production scale expansion, product diversification, and output market access as the most influential determinants of economic sustainability. While larger farm sizes generally increased revenue and net income, profitability was strongly dependent on efficient cost management, particularly variable costs. Overall, strengthening medium-scale operations, supported by investment access, value-added product diversification, and broader market linkages, represents the most effective strategy to improve profitability and ensure the long-term economic sustainability of dry-litter duck farming systems.

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NOVELTY STATEMENT

This study provides an integrated assessment of economic feasibility and economic sustainability of dry-litter duck farming among smallholder farmers in Pinrang Regency, South Sulawesi, using Benefit–Cost analysis and Multi-Dimensional Scaling (MDS). The study identifies farm-scale expansion, product diversification, and market access as the key determinants of long-term economic sustainability in dry-litter duck farming systems.

AUTHORS CONTRIBUTION

AN, contributed to conceptualization, funding acquisition, methodology, resources, data curation, software, validation, writing-original draft, writing-review and editing, and project administration. AA, contributed to conceptualization, validation, visualization and writing-review and editing. SN, contributed to conceptualization, formal analysis, investigation, supervision, visualization and writing-review and editing.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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