

A Case Study on Greenhouse Gas Emission Reduction Potential in Smallholder Pig and Wild Boar Farms in Vietnam

Thi Thu Thao Nguyen^{1*}, Thi Hong Gap Nguyen²

¹Ho Chi Minh City University of Technology and Engineering, Vietnam

²Centre for Environmental Consulting and Communication, Vietnam

*Corresponding author. Email: thaontt@hcmute.edu.vn

ARTICLE INFO

Received: 09/04/2026
Revised: 15/05/2026
Accepted: 26/05/2026
Online First: 27/05/2026
Published: 28/05/2026

KEYWORDS

Global Warming Potential;
Greenhouse Gas;
Livestock Production;
Manure Management;
Wild Boar.

ABSTRACT

Livestock production contributes a large share of total greenhouse gas (GHG) emissions in the agricultural sector, with manure management being one of the major emission sources. This study assessed the GHG emission potential of two household-scaled pig and wild boar farms, as well as a GHG inventory for recommended farm waste mitigation alternatives. The research identified emission "hotspots" produced mostly by enteric digestion and manure management practices. Pig farming had a GHG emission ratio 1.5 times greater than wild boar farming. Because of the dispersed nature of smallholder livestock production and waste management systems, GHG mitigation efficiency has been low. Among the mitigation solutions, fully treating manure with anaerobic digestion (biogas) was found to be the most effective, giving the lowest emission factor and reducing GHG emissions by about 40%–60% when compared to the baseline emissions of the two farming systems. As a result, conducting household-scale GHG inventory would help businesses and policymakers find optimal mitigation solutions and build appropriate emission reduction routes that are linked with national targets.

Doi: <https://doi.org/10.54644/jte.2026.2265>

Copyright © JTE. This is an open access article distributed under the terms and conditions of the [Creative Commons Attribution-NonCommercial 4.0 International License](https://creativecommons.org/licenses/by-nc/4.0/) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial purpose, provided the original work is properly cited.

1. Introduction

The agricultural sector accounted for approximately 42% of global methane (CH₄) emissions and 75% of nitrous oxide (N₂O) emissions annually, with livestock contributing a substantial share [1]. These gases have significantly higher global warming potentials than carbon dioxide (CO₂) (about 28 times for CH₄ and 265 times for N₂O) [2], [3].

Livestock production was responsible for roughly 14.5% to 18% of total global GHG emissions [2]. Rapid economic growth and urbanization in developing economies have placed increasing pressure on the livestock sector, driven by major shifts in dietary patterns from starch-based foods to animal protein [4], [5]. Vietnam has committed to achieving net-zero emissions by 2050 [6]. In this context, livestock contributed up to 30% of total GHG emissions within agricultural sector. Without effective GHG inventory and control, the expansion of production to meet growing food demand could further exacerbate emissions [7]–[9].

Conducting a GHG inventory was thus the first critical step in building a carbon neutrality strategy [10]. The literature review primarily focused on GHG emissions from intensive pig farming systems, with studies conducted in several localities such as Khanh Hoa [11], Lam Dong [12], and Hanoi [6]. Existing studies suggested the need for more in-depth research to assess differences in emissions between large-scale intensive farming and smallholder production [11].

While intensive systems were analyzed in detail by pig categories (e.g., piglets, growing pigs, sows) [11], [12], there was a lack of data and specific emission factors for wild boars in the available literature. Differences in diet and feeding practices for wild boars would result in emission profiles that differ from those of conventional commercial pigs. This study addressed the above research gap by evaluating the GHG emission potential of smallholder farming systems for both commercial pigs and wild boars using a GHG inventory approach. Smallholder livestock systems managed waste in a fragmented manner and

lacked circular practices to fully utilize nutrient and energy flows [13]. Therefore, this study also developed and evaluated GHG inventories for scenarios involving the complete utilization of livestock waste.

2. Materials and Methods

The GHG inventory in this study was based on the national legal framework, including Decree No. 06/2022/ND-CP dated January 7, 2022 on GHG emission mitigation and ozone layer protection, and Circular No. 19/2024/TT-BNNPTNT on technical guidelines for measurement, reporting, and verification of GHG emission mitigation and GHG inventory in the livestock sector. GHG inventory studies in Vietnam have primarily focused on large-scale industrial pig farming [6], [11], with limited attention given to smaller-scale systems such as household farms. In addition, emission data for wild boar farming are currently unavailable. This study carried out a GHG inventory of household-scale farming systems, making a scientific contribution by providing additional reference greenhouse gas emission factors from wild boar farming, assisting in the refinement of the pig and wild boar farming emission report, and supporting local GHG mitigation plans in Vietnam. Therefore, two smallholder farms in Tien Giang Province - one commercial pig farm and one domesticated wild boar (DWB) farm, each with a capacity of 200 animals - were selected for the GHG inventory assessment. Data on GHG emission sources were gathered by surveys and factual information provided by farm owners. The data obtained from these farms were considered comparable, as the farms belonged to livestock cooperatives and operated under standardized protocols; therefore, potential data variability was not taken into account in this study.

The main sources of GHG emissions in livestock production are categorized in Table 1.

Table 1. *The primary sources of GHG emissions in livestock farming.*

No.	Category	Emission source	Activities generating GHGs	GHG
1.	Group 1: Direct GHG Emissions	Feed	Enteric Fermentation	CH ₄
2.		Biological Waste	Animal Waste Management	CO ₂ , CH ₄ , N ₂ O
3.	Group 2: Indirect emissions from purchased energy	Electricity (lights, pumps)	Electricity purchased from external sources	CO _{2eq}
4.	Group 3: Indirect GHG emissions from transportation	Fuel (diesel) for vehicles	Fuel burning for vehicles transporting raw materials (food, medicine, etc.)	CO _{2eq}

The scope of the GHG inventory covered a production cycle across five stages for both farms, including Stage 1: Selecting breeds and importing pigs for rearing (1–10 days); Stage 2: Piglet growth (Days 11–60); Stage 3: Growth (Days 61–110); Stage 4: Before slaughter (Days 111–120 for market pigs / 111–150 for DWBs); Stage 5: Transport to the slaughterhouse. Inventory data were analyzed for the base year, with GHG emissions expressed as the quantity of GHG emitted per animal per year (kg CO_{2eq} head⁻¹year⁻¹). Information on GHG emission sources of the two livestock farms during the rearing stages is described in Table 2.

GHG emission parameters for livestock operations were calculated and determined in accordance with the guidelines of the Intergovernmental Panel on Climate Change (IPCC 2006 [14] and 2019 [15]) and Decision 2626/QD-BTNMT (2022) publishing list of emission factors serving greenhouse gas inventory development [16]. To ensure consistency across different gases, all emissions were converted into carbon dioxide equivalents (CO_{2eq}) [4]. The conversion factors were based on the global warming potential (GWP) of each gas over a 100-year time horizon [3], [7]. In this study, the factors applied are 1, 27, 29.8, and 273 for CO₂, methane - non fossil (CH₄), methane - fossil (CH₄), and N₂O, respectively [17]. Table 2 presents the input data used for GHG calculations, including feed consumption for Equation (2); manure and urine generation as references for determining the contribution of waste to the treatment measures applied in Equations (3)–(5); electricity and water consumption from pumping activities (water usage converted into electricity use) for Equation (7); and diesel consumption for Equation (8).

Table 2. Characteristics of GHG emission sources of the two farms during the rearing stages.

Factor	Emission source	Unit	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5	
			Pig	Boar	Pig	Boar	Pig	Boar	Pig	Boar	Pig	Boar
Feed	Enteric fermentation	Kg head ⁻¹ day ⁻¹	1.5	1.0	2.5	1.8	3.5	2.5	4.0	3.0		
Electricity	Electricity	kWh day ⁻¹	6	4	8	5	10	7	12	10		
Fuel (diesel)	Fuel combustion	L/cycle (10 days)	5	5	5	5	5	5	5	5	6	6
Water usage	Electricity from pumping	L day ⁻¹	2,000	1,000	3,000	1,500	3,000	2,000	4,000	2,500		
Manure	Manure management	Kg day ⁻¹	240	160	350	240	400	280	450	300		

Methane emissions from enteric fermentation were estimated by Equation (1) [18].

$$E_1 = EF_1 \times N \quad (1)$$

where E_1 is CH₄ emissions from enteric fermentation (kg CH₄); N is number of animals; EF_1 is emission factor (kg CH₄/animal/year) calculated according to Equation (2) [18].

$$EF_1 = DMI \times \left(\frac{MY}{1000} \right) \times 365 \quad (2)$$

where DMI is dry matter consumption (kg day⁻¹); MY is CH₄ emissions per unit of dry matter (g CH₄ kg DMI⁻¹). From $EF_1 = 1$ kg CH₄ head⁻¹ year⁻¹ [15], [16], E_1 can be calculated based on the total number of rearing days.

Managing animal waste was estimated by Equations (3)–(6), respectively [15], [18].

$$CH_{4Manure} = \sum_S (N \times VS \times AWMS_S \times EF_C) / 1000 \quad (3)$$

where $CH_{4Manure}$ is total CH₄ emissions from livestock waste management (kg CH₄); S is type of waste treatment system; $AWMS_S$ is percentage of waste treated in the treatment system; EF_C is CH₄ emission factor according to the waste treatment system (g CH₄ kg VS⁻¹), 155.4 g CH₄ kg VS⁻¹ for uncovered anaerobic lagoon and 21.2 g CH₄ kg VS⁻¹ for anaerobic digestion - biogas [15] due to a waste treatment process for both farms; VS is volatile solid excretion factor for each type of livestock (kg VS head⁻¹) calculated according to Equation (4) [15], [18].

$$VS = VS_{rate} \times \frac{TAM}{1000} \quad (4)$$

where VS_{rate} is the coefficient of volatile solid excretion for each type of livestock, reaching 5.8 kg (1000 kg mass)⁻¹ day⁻¹ [15], [16]; TAM is the typical weight of the livestock, approximately 3 kg, 30 kg, 60 kg and 90 kg corresponding to stages 1–5 in pig production and 1 kg, 10 kg, 20 kg and 30 kg corresponding to stages 1–5 in DWB production. N₂O was calculated using Equation (5) [15], [18].

$$N_2O_{manure} = \sum_S (N \times Nex \times AWMS_S \times D) \times EF_N \times \frac{44}{28} \quad (5)$$

where N_2O_{manure} is direct N₂O emissions from livestock waste management (kg N₂O); D is rearing days; EF_N is direct N₂O emission factor according to waste treatment system, reaching 0.0006 kg N₂O-N kg N⁻¹ and 0 (kg N₂O-N kg N⁻¹) for anaerobic digestion and uncovered lagoon respectively [15]; Nex is nitrogen excretion (kg N head⁻¹) determined using Equation (6) [15], [18].

$$N_{ex} = N_{rate} \times \frac{TAM}{1000} \quad (6)$$

where N_{rate} is nitrogen excretion rate, reaching $0.42 \text{ kg N (1000 kg of animal weight)}^{-1} \text{ day}^{-1}$ [16].

The Equation (7) was used to calculate GHG emissions from electricity usage activities in livestock farming [18].

$$TPT_D = AD \times EF_e \quad (7)$$

where TPT_D is total indirect CO_2 emissions from electricity usage purchased from the grid (tons CO_{2eq}); AD is total amount of electricity consumed purchased (MWh); EF_e is CO_2 emission factor (tons $\text{CO}_{2eq} \text{ MWh}^{-1}$) is $0.6592 \text{ tCO}_2 \text{ MWh}^{-1}$ [19].

GHG emissions related to burning fuels are calculated according to Equation (8) [14], [18].

$$TPT_F = \sum_i (AD_{F,i} \times EF_{F,i}) / 1000 \quad (8)$$

where TPT_F denotes the total CO_2 equivalent emissions of type i GHGs caused directly by fuel combustion activity F (tons CO_{2eq}); i is type of GHG; F is type of fuel used for energy generation combustion; $AD_{F,i}$ is fuel consumption of F (TJ); $EF_{F,i}$ is emission factor of GHG for fuel type F (kg/TJ). In this study, EF s for CO_2 , CH_4 , and N_2O were $74100 \text{ kg CO}_2/\text{TJ}$; $3.9 \text{ kg CH}_4/\text{TJ}$; and $3.9 \text{ kg N}_2\text{O}/\text{TJ}$ [14], respectively.

GHG inventory is the first stage in switching farms from traditional waste management to recycling [13]. Therefore, alternative scenarios aimed at circular waste management were proposed (Table 3). These scenarios aimed to minimize the release of farm waste into the environment through commonly applied, low-cost solutions suitable for the study area, complying with Decree No. 14/2021/ND-CP regulating administrative penalties for violations related to livestock waste management [20]. Manure management strategies that promote the collection and recovery of nutrients and energy contained in manure can further contribute to GHG emission reduction [21]. Composting and biogas recovery can reduce CH_4 and N_2O emissions [22], [23], while improved equipment and machinery (Scenario 6) can lower indirect emissions from energy usage [23], [24].

Table 3. Scenarios of emission reduction solutions.

Symbol	Emission reduction solutions	Type
S0	50% Anaerobic Digestion - Biogas, 50% uncovered lagoon	Current status
S1	50% Anaerobic Digestion - Biogas burned for fuel, 50% uncovered lagoon	Scenario
S2	50% Anaerobic Digestion - Biogas, 50% compost	
S3	50% Anaerobic Digestion - Biogas burned for fuel, 50% compost	
S4	100% Anaerobic Digestion - Biogas	
S5	100% Anaerobic Digestion - Biogas burned for fuel	
S6	Electric power for pump $1.5 \text{ kW (15L minute}^{-1}\text{)}$	

The scenarios show a clear preference for anaerobic digestion - biogas systems and anaerobic digestion with biogas combustion for fuel in scenarios S4 and S5, as well as the combined application of anaerobic digestion and composting in scenarios S2–S3. The anaerobic digestion - biogas combustion for fuel option replaced the current anaerobic digestion - biogas system, in which the generated biogas is not utilized on-site. This modification helps reduce emissions associated with anaerobic decomposition and enhances avoided emission through energy recovery from waste [21]. Furthermore, like in scenario S6, inputs with lower emission intensity were an emission reduction option through technical advancements [21] such as employing lower-power pumps while maintaining operating efficiency equivalent to existing farm equipment.

3. Results and Discussion

Figure 1 depicts statistics on GHG emission sources for pig and DWB production over a year period. It reveals that the pig farm consumed more feed, electricity, and water than the DWB farm during the first three stages. However, due to the longer duration of Stage 4, all operational activities on the DWB farm require greater input consumption, resulting in differences in the inventory outcomes between the two farms.

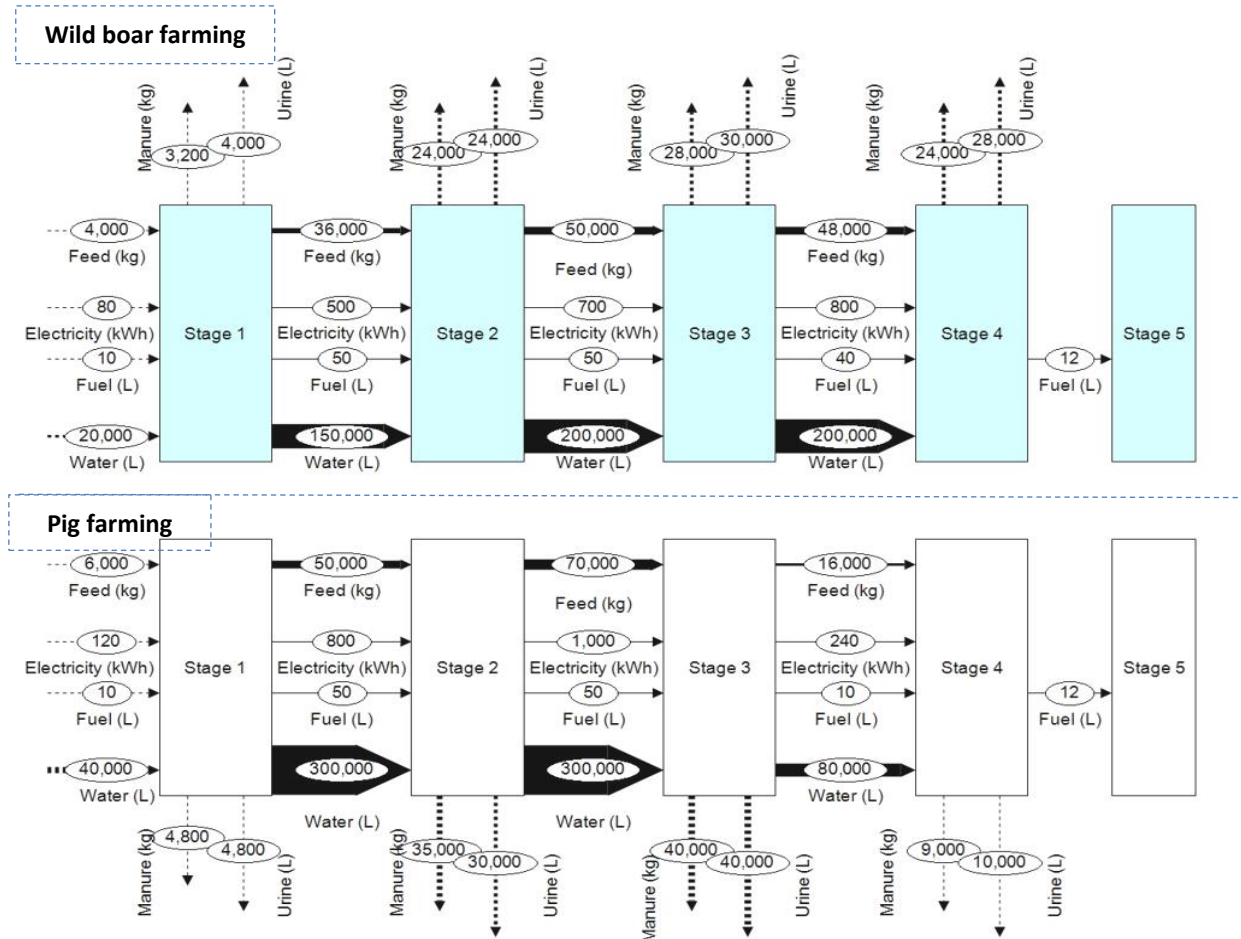


Figure 1. Statistics on GHG emission sources for five stages of pig and wild boar farms.

The literature-based GHG assessment results indicated that pig farming generated emissions from three main sources: electricity use [11], enteric digestion, and manure management [11], [12], which is consistent with the findings of this study. The computed GHG findings for the two farms (Figure 2) show that the pig farm had a greater emission factor than the DWB farm, at 238 kg CO_{2eq} head⁻¹ year⁻¹ and 152 kg CO_{2eq} head⁻¹ year⁻¹, respectively. These values were higher than those reported for large-scale intensive farming systems, such as in the studies of Son and Tam (2023) [11], and Thuan et al. (2017) [12], likely due to better feed and energy efficiency in larger operations [22]. Across two farms' production stages, waste management and enteric fermentation produced the most GHGs. Only in stage 1 were emissions from enteric fermentation (accounting for approximately 60%) about three times higher than those from manure management. From stages 2 to 4, emissions from manure management exceeded those from enteric fermentation. This suggests that as pigs grew, so did the burden on waste management systems. In stage 4, although wild boars have a longer rearing cycle and smaller weight compared to market pigs, DWB farms generate more greenhouse gases. This difference demonstrates that animal weight does not contribute significantly to greenhouse gas emissions in waste management; instead, the contribution is mainly due to duration.

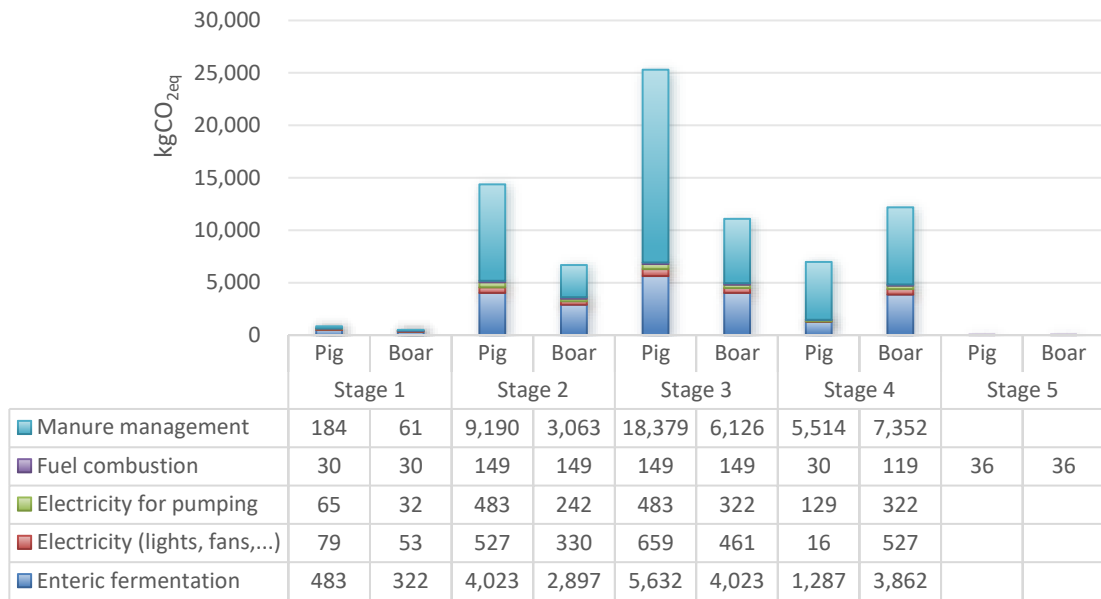


Figure 2. GHG emission results from the two existing farms.

Figure 3 and Table 4 present the GHG emission results across production stages under different mitigation scenarios. For the pig farm, GHG emission rates were highest in stage 2 (30%–37%) and stage 3 (47%–53%). In contrast, for the DWB farm, the highest shares occurred in stage 3 (35%–37%) and stage 4 (33%–40%). This difference can be explained by variations in rearing duration and weight gain. In DWB production, stages 2, 3, and 4 had nearly similar production duration; however, the body weight in stage 4 was approximately double that of stage 2, leading to increased emissions from both enteric fermentation and manure management.

In comparison to S0, emissions in scenarios S4 and S5 were reduced by almost twofold in stage 2 and 2–3 times in stage 3 for the pig farm. S4 and S5 showed similar twofold reductions in stages 3 and 4 of the DWB farm. Overall, the findings suggest that mitigation strategies were more effective when used in the commercial pig farm.

Table 4. The amount of GHG emissions from production stages of the two farms under various scenarios.

Stage	Scenarios											
	S1		S2		S3		S4		S5		S6	
	Pig	Boar	Pig	Boar	Pig	Boar	Pig	Boar	Pig	Boar	Pig	Boar
1	928	564	1,487	1,109	1,575	1,175	701	452	878	584	819	488
2	14,078	6,866	11,761	8,427	11,467	8,613	7,446	4,371	6,858	4,742	14,219	6,603
3	24,024	10,993	15,855	11,067	14,577	10,978	11,451	6,465	8,893	6,287	25,149	10,980
4	6,523	11,855	3,706	10,613	3,253	10,285	2,820	6,642	1,915	5,987	6,935	12,080
5	36	36	36	36	36	36	36	36	36	36	36	36

Unit: (kg CO_{2eq} year⁻¹)

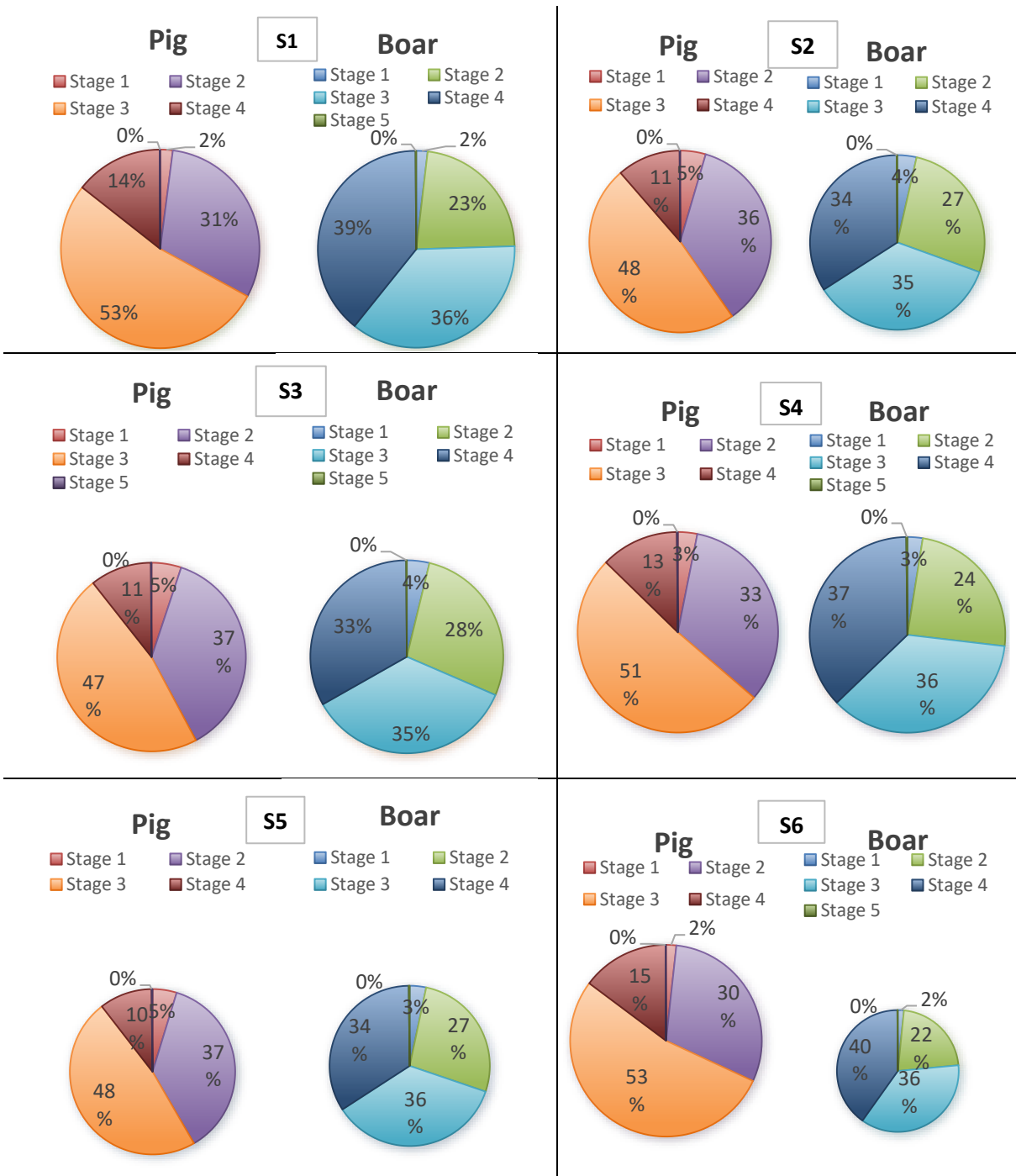


Figure 3. GHG emission rates of different farming stages under various scenarios.

In addition, GHG emissions calculated for production activities across the scenarios are presented in Figure 4. The total emissions of scenarios S1 and S6 were nearly equal to those of S0. For the pig farm, the GHG emission factor gradually decreased from scenarios S1 to S5, reaching the lowest level at 93 kg CO_{2eq} head⁻¹ year⁻¹ in scenario S5. For the DWB farm, the emission factors remained relatively stable across scenarios S1–S3, with the lowest value of approximately 90 kg CO_{2eq} head⁻¹ year⁻¹ observed in scenarios S4 and S5. Compared to S0, the scenarios with the lowest emission factors reduced overall GHG emissions by 40%–60% for both farms. This demonstrated that waste treatment via anaerobic digestion - biogas was a potential method for significantly reducing GHG emissions. When waste was thoroughly treated with a biogas system, emissions were decreased by more than 80% [11], [12].

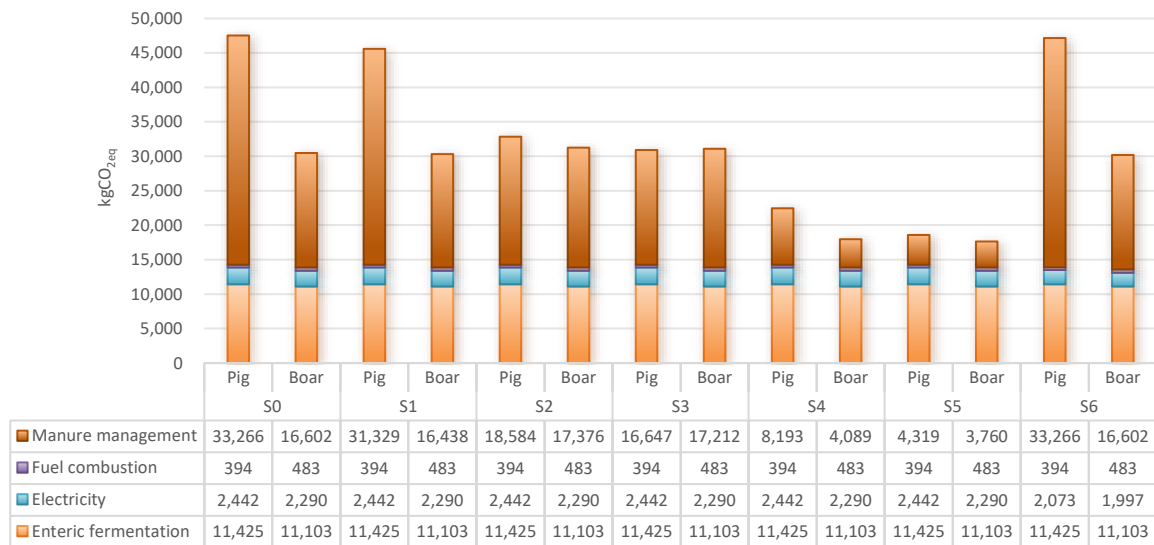


Figure 4. The amount of GHG emissions from farming activities on the two farms under various scenarios.

Overall, due to the dispersed nature of smallholder farms on and waste management systems, GHG mitigation efficiency has been low. The inventory results identified "hotspots" for emissions, such as enteric digestion and manure management [25]–[27]. They would support businesses and policymakers in identifying optimal mitigation solutions and designing appropriate emission reduction pathways aligned with national targets [6].

4. Conclusions

This study conducted a GHG inventory of two smallholder farms raising commercial pigs and domesticated wild boars. The results identified current manure management practices as the major source of GHG emissions. Accordingly, mitigation and recovery scenarios were developed and assessed for their emission reduction potential. Compared with the baseline, scenarios incorporating anaerobic digestion and biogas recovery reduced GHG emissions by approximately 2–3 times. These findings highlight the importance of household-level GHG inventories in improving national emission databases [9], [10], [28], and providing more accurate assessments of the environmental impacts of pig and wild boar production.

Acknowledgments

The authors warmly acknowledge Ho Chi Minh City University of Technology and Engineering, Vietnam, for allowing us to complete this study under perfect conditions. The authors thank the farm owners who shared information regarding the field study and the surrounding area.

Conflict of Interest

The authors declare no conflict of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT in order to English language editing. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

- [1] H. Blonk, M. v. Paassen, N. Draijer, M. Tyszler, N. Braconi, and J. v. Rijn, "Agri-footprint 6 Methodology Report," *Groen van Prinsterersingel 45, 2805 TD Gouda, The Netherlands*, 2023.
- [2] B. Magadia, R. Demafelis, A. Obligado, H. Avilla, E. P. Estante, and G. A. Briones, "Analyzing Carbon and Nitrogen Balances in Swine Production Systems: A Methodology to Evaluate the Global Warming Potential of Swine Production in the Philippines," *Journal of Environmental Science and Management*, vol. sp, p. 1, 2025
- [3] H. Li, S. Hu, and H. Tong, "Carbon footprint of household meat consumption in China: A life-cycle-based perspective," *Applied Geography*, vol. 169, p. 103325, 2024.
- [4] H. Li, S. Hu, and H. Tong, "Carbon footprint of household meat consumption in China: A life-cycle-based perspective," *Applied Geography*, vol. 169, p. 103325, 2024.
- [5] R. Sharma, T. T. Nguyen, and U. Grote, "Changing Consumption Patterns-Drivers and the Environmental Impact," *Sustainability*, vol. 10, p. 4190, 2018.
- [6] H. T. Hue, "Assessing greenhouse gas mitigation costs using the macc tool in livestock waste management in Hanoi," (in Vietnamese), *Hydraulic engineering and environmental science*, vol. 96, 12/2025.
- [7] B. Kunter and N. Keskin, "Agricultural and natural sciences Theory, current researches and new trends," *Cetinje, Montenegro*, 2020.
- [8] P. Nguyen Thi Kim and T. T. L. Le, "Trade-offs in greenhouse gas emissions for financial efficiency in chili pepper and chicken farming models in Hon Dat district, Kien Giang province," (in Vietnamese), *Can Tho University Journal of Science*, vol. 59, pp. 42-53, 2023.
- [9] G. Hao, H. Zhu, and Y. Cui, "Measurement and Influencing Factors of Carbon Emissions of China's Livestock Husbandry in the Post-COVID-19 Era—Based on the Supply-Side Perspective," *Sustainability*, vol. 15, p. 913, 2023.
- [10] N. V. Hieu and N. H. Nam, "Current situation of greenhouse gas emissions in Vietnam: Opportunities and challenges," (in Vietnamese), *Vietnam Journal of Hydrometeorology*, vol. 728, pp. 51-66, 2021.
- [11] T. S. Nguyen and T. T. Tran, "Assessment of greenhouse gas emissions from the pig production in Cam Lam, Khanh Hoa province," (in Vietnamese), *Journal of fisheries science and technology*, pp. 039-047, 2023.
- [12] N. T. T. Thuan, C. T. Anh, L. Q. Huy, and N. T. B. Dung, "Assessment of greenhouse gas emissions from the pig production in Lam Dong," (in Vietnamese), *Journal of science and technology development*, vol. 20, 2017.
- [13] D. T. H. Van, T. Phuong, N. T. My, and C. T. Son, "Assessment of the Current Status of Waste Management and Proposed Improvement Solutions for Pig-Farms in Hatinh Province," (in Vietnamese), *Proceedings of the National Scientific Conference "Agricultural and Rural Environment and Sustainable Development"*, 2024.
- [14] IPCC, "2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy," 2006.
- [15] IPCC, "2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. Volume 4: Agriculture, Forestry and Other Land Use," 2019.
- [16] M. O. N. R. A. E. O. Vietnam, "Decision No. 2626/QĐ-BTNMT dated October 10, 2022 issued by the Ministry of Natural Resources And Environment Of Vietnam, Publishing list of emission factors serving greenhouse gas inventory development. Ministry of Natural Resources And Environment Of Vietnam," (in Vietnamese), 2022.
- [17] I. P. o. C. Change, "IPCC Global Warming Potential Values," 2020.
- [18] M. o. a. a. R. Development, "Circular No. 19/2024/TT-BNNPTNT dated December 3, 2024, issued by the Ministry of Agriculture And Rural Development, Regulating techniques for measurement, reporting, verification of greenhouse gas emission reduction and greenhouse gas inventory in the livestock sector. Ministry of Agriculture and Rural Development," (in Vietnamese), 2024.
- [19] M. o. N. R. a. Environment and C. C. Department, "Official Document No. 1726/BDKH-PTCBT dated December 3, 2024, issued by the Ministry of Natural Resources and Environment and Climate Change Department, The announcement of the results of calculating the emission factor of Vietnam's power grid in 2023. Ministry of Natural Resources and Environment and Climate Change Department," (in Vietnamese), 2023.
- [20] V. Government, "Decree No. 14/2021/ND-CP dated March 1, 2021, issued by the Vietnam Government, Regulating penalties for administrative offences involving animal husbandry. The Vietnam Government," (in Vietnamese), 2021.
- [21] P. J. Gerber, Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G., "Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome," 2013.
- [22] M. M. Scholtz, J. B. J. Van Ryssen, H. H. Meissner, and M. C. Laker, "A South African perspective on livestock production in relation to greenhouse gases and water usage," *South African Journal of Animal Science*, vol. 43, p. 247, 2013.
- [23] M. M. Scholtz, J. B. J. Van Ryssen, H. H. Meissner, and M. C. Laker, "A South African perspective on livestock production in relation to greenhouse gases and water usage," *South African Journal of Animal Science*, vol. 43, p. 247, 2013.
- [24] T. H. Son, V. V. Doanh, and L. N. Thuan, "Study on greenhouse gas inventory according to ISO 14064-1:2018 standard in supporting industry enterprises," (in Vietnamese), *Environment Magazine*, vol. Special topic II, pp. 8-15, 2024
- [25] A. Kool, H. Blonk, T. Ponsioen, W. Sukkel, H. Vermeer, J. d. Vries, *et al.*, "Carbon footprints of conventional and organic pork," *Blonk Milieu Advies BV, The Netherlands*, 2010.
- [26] L. Zhang, G. Yin, Z. Wei, W. Li, C. Cui, M. Wang, *et al.*, "Potential and Pathways of Carbon Emission Reduction in China's Beef Production from the Supply Chain Perspective," *Agriculture*, vol. 14, p. 1190, 2024.
- [27] Y. Yu, Q. Li, Y. Bao, E. Fu, Y. Chen, and T. Ni, "Research on the Measurement and Influencing Factors of Carbon Emissions in the Swine Industry from the Perspective of the Industry Chain," *Sustainability*, vol. 16, p. 2199, 2024.
- [28] X. Dai, X. Wu, Y. Chen, Y. He, F. Wang, and Y. Liu, "Real Drivers and Spatial Characteristics of CO₂ Emissions from Animal Husbandry: A Regional Empirical Study of China," *Agriculture*, vol. 12, p. 510, 2022.

Thi Thu Thao Nguyen is a lecturer at the Faculty of Chemical and Food Technology, HCMC University of Technology and Engineering in Vietnam. Majoring in resource and environmental management, as well as environmental science.

Email: thaontt@hcmute.edu.vn. ORCID: <https://orcid.org/0009-0004-2647-8974>. Tel: 0942886070.

Thi Hong Gap Nguyen specializes in Environmental Consulting and Communication, Vietnam.

Email: gapnguyen388@gmail.com. ORCID: <https://orcid.org/0009-0006-0971-1169>