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Additional data collection for Tier 2 greenhouse gas inventory in pig production in Vietnam

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ABSTRACT

This study aims to strengthen the accuracy of Tier 2 greenhouse gas (GHG) inventories for Vietnam's pig sector by addressing key data gaps in transitioning from the Tier 1 approach. Field surveys, focus group discussions (FGDs), and expert consultations were conducted to collect country-specific data on pig growth stages, sow productivity, breed structure, feeding practices, and manure management across four time periods (1994–2000, 2001–2010, 2011–2020, and 2021–present). Results indicate that field survey provide the most reliable and representative source for quantitative parameters such as feed intake and productivity, while FGDs are particularly effective for qualitative assessments of breed distribution, farming systems, and manure management. Expert judgment is valuable for historical estimates but is less precise for dynamic factors. The study recommends periodic data collection every 3–5 years for pig production stages, sow productivity, breed structure, and manure management; every 5 years for feed intake and composition; and immediate updates when farming systems change. Implementing these recommendations will significantly improve the accuracy and transparency of Vietnam's livestock GHG inventory, thereby supporting more effective GHG reporting and the development of sustainable livestock policies.

Keywords: *Greenhouse gas inventory; Tier 2, Pig production; Data collection; Vietnam; Data gaps.*

Introduction

Pig production is a cornerstone of Vietnam's livestock industry and a major source of human dietary protein. With a national herd exceeding 25 million head in 2023 and projected growth in the coming decade, the sector contributes substantially to food security and rural livelihoods. At the same time, it represents a significant source of greenhouse gas (GHG) emissions. In 2020, emissions from the livestock sector were estimated at approximately 31 million tons CO_2-equivalent, with pig manure management accounting for nearly 70% of methane (CH_4) and nitrous oxide (N_2O) emissions. Addressing these emissions is therefore critical to Vietnam's commitment to achieving net-zero by 2050.).

The Intergovernmental Panel on Climate Change (IPCC) provides a tiered framework for estimating greenhouse gas (GHG) emissions, with Tier 1, Tier 2 and Tier 3 methodologies offering varying levels of detail and accuracy. The Tier 1 method relies on default emission factors that are not country-specific, making it less precise in reflecting national livestock characteristics and leading to high levels of uncertainty in GHG estimates (IPCC, 2006). By contrast, the Tier 2 and 3 method, which requires more detailed data, is recommended for key emission sources (e.g. enteric fermentation for cattle, manure management for pigs). It should be applied to livestock species that contribute significantly to a country's total emissions (IPCC, 2019).

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To apply the Tier 2 method it is recommended to use country-specific data to improve accuracy. To date, Viet Nam has used the Tier 1 method to estimate methane emissions from key livestock emission sources. However, the adoption of the IPCC Tier 2 method presents an opportunity to enhance inventory accuracy by accounting for national livestock production systems and management practices. A Tier 2 approach also allows for a more precise assessment of the impact of policies and mitigation measures in the livestock sector, strengthening the country's ability to track GHG reductions in line with its commitment to achieving net-zero emissions by 2050.

Nonetheless, the shift to Tier 2 also reveals major challenges, particularly data gaps in disaggregated livestock populations, input parameters for developing country-specific emission factors, and manure management systems. To address these issues, the IPCC recommends a systematic and transparent approach, including: (i) identifying and prioritizing key data gaps; (ii) utilizing existing or proxy data, field surveys, measurements, and modeling; (iii) expanding datasets through literature reviews and statistical methods; and (iv) ensuring transparency by documenting data sources, methodologies, and assumptions.

The objective of this study is to enhance the accuracy of Vietnam's livestock GHG inventory by addressing critical data deficiencies in pig production. Specifically, the study identifies priority parameters, develops methodologies for their collection, and consolidates data across four periods (1994–2000, 2001–2010, 2011–2020, and 2021–present). The outcomes are expected to strengthen the scientific basis of the national inventory, improve compliance with international reporting standards, and provide evidence for the design of mitigation policies in the livestock sector.

Materials and methods

Study scope

The study aimed to address data gaps essential for Tier 2 greenhouse gas (GHG) inventories of pig production in Vietnam. Key parameters included pig growth stages, sow productivity, breed composition, feed intake and composition, and manure management. Data covered four time periods (1994–2000, 2001–2010, 2011–2020, and 2021–present) and were collected from March to October 2024.

Data collection methods

Following a review of existing data and information sources, key gaps were identified and a mixed-method approach was developed by combining expert judgment, focus group discussions (FGDs), farmer surveys, and field sampling methods.

Expert judgment: Ten specialists in pig nutrition, production, and waste management defined pig stages, feeding systems, and manure flows.

FGDs with provincial livestock officers (PLOs): Livestock officers from six provinces represented regional farming practices and system typologies.

Farmer interviews: 370 households and commercial farms were interviewed using standardized questionnaires covering herd structure, growth, reproduction, feeding, and manure handling.

Parameter-specific strategies

Manure management fractions: Estimated via expert judgment, provincial FGDs, farmer surveys, and validated with survey data.

Feed information of each farming system and period was derived from expert judgment and survey data. Additionally, data on feed rations were collected using intra- and

extrapolation methods, and calculations followed IPCC guidelines.

Growth and productivity parameters: Combined from expert judgment, provincial FGDs and farm surveys.

Data Processing

Data were processed through interpolation and extrapolation following IPCC guidelines, combined with statistical methods to ensure accuracy and consistency. Where multiple sources existed, mean values were calculated and variability assessed using standard deviations. Interpolation and extrapolation were applied to fill temporal gaps. Microsoft Excel was used for statistical processing and consistency checks.

Ethics

Participation in surveys and FGDs was voluntary, with informed consent obtained. All results are presented in aggregated form to ensure confidentiality

Results and discussions

Pig population structure and production stages

Table 1 illustrates the chronological progression of pig-raising stages—weaning, growing, and fattening—across four distinct periods (1994–2000, 2001–2010, 2011–2020, and 2021–present). The classification is further stratified by breed (local, hybrid, exotic), region (North, Central, South), and farming system (household, commercial).

A comparison of survey data with expert judgment and focus group discussion (FGD) results showed no statistically significant differences in the estimated start and end times of the weaning and growing stages across the first three periods. However, greater variability was observed in the fattening stage, particularly in the estimated duration to slaughter, as reflected in higher standard deviations (SDs). In the most recent period (2021–present), survey data revealed that the fattening stage ended significantly earlier than estimates derived from expert judgment and FGDs, suggesting possible shifts in farming practices, genetics, or feeding strategies.

Data reliability and implications for Tier 2 inventory

Overall, data obtained from three independent sources (farm surveys, expert judgment, and FGDs) demonstrated a high degree of consistency. Among them, direct data collection from pig farmers provided the highest experiential accuracy, as their firsthand involvement in livestock management offers valuable insights into the factors influencing raising and feeding practices. According to expert insights in the pig farming sector, production trends typically undergo significant shifts within a 5–10 year timeframe. Consequently, to ensure that Tier 2 inventories remain current and reflective of actual practices, data collection should occur every 5–10 years to capture timely developments and emerging trends in pig productionon.

Table 1. Pig population structure and production stages

Period	Breed	Stage	North						Central						South					
			Weaning		Growing		Fattening		Weaning		Growing		Fattening		Weaning		Growing		Fattening	
			Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish	Start	Finish
1994-2000[1,2]	Local	Household	63	93	93	162	162	225	63	93	93	162	162	225	60	90	90	160	160	220
	Hybrid		49	85	85	156	156	212	49	85	85	156	156	211	50	85	85	155	155	210
	Exotic		30	65	65	145	145	200	30	65	65	145	145	200						
2001-2010[1,2]	Local		62	92	92	160	160	223	61	91	91	160	160	223	60	90	90	160	160	220
	Hybrid		44	80	80	148	148	203	44	80	80	148	148	203	45	80	80	147	147	200
	Exotic		30	65	65	145	145	200	30	65	65	145	145	200	30	64	64	135	135	188
2011-2020[1,2]	Local		60	90	90	160	160	220	60	90	90	160	160	220	60	90	90	160	160	220
	Hybrid		45	73	73	132	132	193	45	73	73	132	132	193	45	72	72	132	132	190
	Exotic		28	60	60	130	130	184	28	60	60	130	130	184	29	60	60	126	126	178
2021-present[1,2,3]	Local		34	65	65	119	119	181	33	71	71	116	116	165	35	75	75	140	140	190
	Hybrid		31	68	68	122	122	183	32	69	69	118	118	183	35	72	72	120	120	190
	Exotic		27	58	58	132	132	180	24	56	56	123	123	171	27	59	59	132	132	180
1994-2000[1,2]	Local	Commercial	55	93	93	160	160	205	68	103	103	165	165	218	60	100	100	160	160	210
	Hybrid		40	60	60	120	120	180	50	80	80	150	150	205						
	Exotic		50	80	80	146	146	200	40	71	71	133	133	190	50	80	80	146	146	200
2001-2010[1,2]	Local		63	100	100	162	162	213	63	100	100	161	161	213	60	100	100	160	160	210
	Hybrid		45	75	75	140	140	193	45	75	75	140	140	193	45	75	75	140	140	190
	Exotic		30	60	60	135	135	185	30	60	60	135	135	243	30	60	60	130	130	180
2011-2020[1,2]	Local		62	100	100	160	160	210	61	100	100	160	160	210	60	100	100	160	160	210
	Hybrid		42	67	67	127	127	185	42	66	66	126	126	185	42	65	65	125	125	180
	Exotic		28	56	56	126	126	174	28	56	56	125	125	174	28	56	56	120	120	169
2021-present[1,2,3]	Local		39	75	75	138	138	184	43	78	78	138	138	188	35	70	70	130	130	180
	Hybrid		30	65	65	121	121	180	33	64	64	121	121	182	35	62	62	120	120	180
	Exotic		25	55	55	127	127	179	24	54	54	123	123	173	25	56	56	126	126	174

Data sources: 1: Expert judgment; 2: Focus group discussion (FGD); 3: Survey.

Reproductive performance and sow productivity

Data on sow reproductive stages and productivity were collected through focus group discussions (FGDs) and expert judgment for the first three periods (1994–2020). Parameters such as age at first mating, first farrowing, first/last weaning, first mating weight, average sow weight at weaning, and farrowing interval were estimated from FGDs. Expert judgment was used to estimate the number of piglets per litter, number of weaned pigs per litter, birth weight, and weaning weight. Weaning period duration and number of litters per sow were obtained from both FGDs and expert judgment, showing no notable differences between the two sources. In the most recent period (2021–present), survey data were integrated to calculate mean values for all parameters (Table 2 and table 3).

Across the first three periods, FGDs and expert judgment provided broadly consistent estimates. In the most recent period, survey data showed minimal differences in household farms but revealed significant discrepancies in commercial systems, particularly in weaning age and sow lifespan. Survey data indicated a shorter productive lifespan of sows in commercial farms compared to FGD estimates, likely reflecting higher culling rates to maintain herd productivity. On average, breeding sows remain productive for 4–5 years, suggesting that data collection every 4–5 years would adequately capture one full production cycle and provide timely updates on reproductive efficiency and productivity trends.

Data reliability and implications for Tier 2 inventory

Overall, FGDs and expert judgment were deemed reliable for the earlier periods, particularly when two independent data sources were available. However, discrepancies in the most recent period-such as in first mating weight and sow weight at weaning-highlight limitations, as farmers rarely record these parameters and survey estimates are required. Survey data based on detailed farm records are more representative of current commercial practices and therefore crucial for Tier 2 inventory updates. To improve accuracy and consistency, a dual-cycle approach is recommended: (i) expert consultations every 2–3 years to track emerging trends in sow productivity, and (ii) comprehensive farm surveys every 3–5 years to provide robust, up-to-date data. This approach balances accuracy, cost-effectiveness, and policy relevance while ensuring compliance with international reporting requirements.

Table 2. Reproductive performance and sow productivity in householdsData sources: 1: Expert judgment; 2: Focus group discussion (FGD); 3: Survey; *: 1994-2020: FGDs and 2021-present: FGDs and survey.

Region	Indicator \ Period		1994-2000			2001-2010			2011-2020			2021-present		
			Local	Hybrid	Exotic	Local	Hybrid	Exotic	Local	Hybrid	Exotic	Local	Hybrid	Exotic
North	First mating weight (kg)[2,3]		35	63	80	38	75	90	47.5	90	106.5	58.75	109.23	123.28
	Gestating period (days)*	Start	155	177	210	158	168	215	160	180	223	212	237	237
		Finish	269	291	324	272	282	329	274	294	337	329	350	350
	Aver. weight of sows at weaning in 2nd-4th litter (kg)[2,3]		55	150	200	70	175	200	81.5	177.5	195	78.25	180.63	206.41
	Lactating period (days)*	Start	329	337	354	342	324	359	329	339	365	356	376	376
		Finish	1858	1722	1784	1852	1712	1754	1802	1742	1654	1580	1634	1634
	Number of piglets/litter[1,3]		9.5	10	9.5	10	10.5	10	10	10.5	10	10.75	11.17	10.83
	Number of weaned pigs/litter[1,3]		8.5	9	8.5	9	9.5	9	9	9.5	9	10	10.35	10.03
	Birth weight/piglet[1,3]		0.5	0.72	1.1	0.5	0.8	1.2	0.55	0.85	1.25	0.73	1.17	1.42
	Weaning weight/pig[1,3]		7	10	7	7	9	7	7	10	7	10.5	7.3	6.82
	Number of days weaned[3]		59	48	35	57.50	42.5	30	52.25	39.5	30	38	32.53	27.25
	Number of litters/year[3]		1.75	1.78	1.80	1.75	1.85	1.88	1.90	1.90	2.01	1.93	2.07	2.14
	Farrowing interval (days)[2,3]		219	192	203	216	190	197	182	167.5	162.00	176	162	172
	Weight loss after weaning……kg[3]											25	31.43	21.21
	Weaning weight loss of sows (eq. to…% of BW)[3]											30	20.83	9.75
Central	First mating weight (kg)[2,3]		35	63		38	75	90	45	90	112.5	50	94.44	121.38
	Gestating period (days)*	Start	155	177	210	158	168	215	160	180	223	192	197	197
		Finish	269	291	324	272	282	329	274	294	337	306	309	309
	Aver.weight of sows at weaning in 2nd-4th litter (kg)[2,3]		55	150		70	175	200	87.5	185	210	91.88	183.88	215.77
	Lactating period (days)*	Start	329	337	354	342	324	359	329	339	365	344	327	327
		Finish	1858	1722	1784	1852	1712	1754	1802	1742	1654	1814	1686	1686
	Number of piglets/litter[1,3]		9.5	10	9.5	10	10.5	10	10	10.5	10	9.88	11.23	11.04
	Number of weaned pigs/litter[1,3]		8.5	9	8.5	9	9.5	9	9	9.5	9	9.38	10.31	10.15
	Birth weight/piglet[1,3]		0.5	0.72	1.1	0.5	0.8	1.2	0.55	0.85	1.25	0.72	1.07	1.42
	Weaning weight/pig[1,3]		7	10	7	7	9	7	7	10	7	5.31	6.85	6.67
	Number of days weaned[3]		58.75	48	35	57.5	42.5	30	54.25	40.25	28.5	32.92	32.07	25.97
	Number of litters/year[3]		1.75	1.79	1.80	1.75	1.85	1.85	1.81	1.85	1.99	1.85	2.05	2.14
	Farrowing interval (days)[2,3]		218.5	192	203	215.5	190	197	209	185	174	196.5	172	191.5
	Weight loss after weaning……kg[3]											19	20.26	24.4
	Weaning weight loss of sows (eq. to…% of BW)[3]											16	15.44	14.05

Region	Indicator \ Period		1994-2000			2001-2010			2011-2020			2021-present		
			Local	Hybrid	Exotic	Local	Hybrid	Exotic	Local	Hybrid	Exotic	Local	Hybrid	Exotic
South	First mating weight (kg)[2,3]					50	75	100	55	80	110	65	70	121.47
	Gestating period (days)*	Start									243			237
		Finish									337			341
	Aver. weight of sows at weaning in 2nd-4th litter (kg)[2,3]					100	150		110	160	200	120	150	221.84
	Lactating period (days)*	Start									365			370
		Finish									776			1530
	Number of piglets/litter[1,3]		9.5	10	9.5	10	10.5	10	10	10.50	10	10	10.25	10.82
	Number of weaned pigs/litter[1,3]		8.5	9	8.5	9	9.5	9	9	9.50	9	9	9.25	9.81
	Birth weight/piglet[1,3]		0.5	0.72	1.10	0.50	0.80	1.20	0.55	0.85	1.25	0.55	0.93	1.31
	Weaning weight/pig[1,3]		7	10	7	7	9	7	7	10	7	6	6	7.15
	Number of days weaned[3]		60	50	35	60	41.25	29.5	57.5	37.25	28.13	35	31.33	27.77
	Number of litters/year[3]		1.8	1.75	1.8	1.8	1.81	1.88	1.83	1.83	2.00	1.85	2	2.87
	Farrowing interval (days)[2,3]					202	200	192	202	197	177	197	187	170.5
	Weight loss after weaning……kg[3]												5	18.9
	Weaning weight loss of sows (eq. to…% of BW)[3]												4	18.24

*Data sources: [1]: Expert judgment; [2]: Focus group discussion (FGD); [3]: Survey; *: 1994-2020: FGDs and 2021-present: FGDs and survey.*

Table 3. Sow productivity in commercial farms

Region	Indicator \ Period		1994-2000			2001-2010			2011-2020			2021-present		
			Local	Hybrid	Exotic	Local	Hybrid	Exotic	Local	Hybrid	Exotic	Local	Hybrid	Exotic
North	First mating weight (kg)[2,3]		30	75	115	40	78	105	40	96.5	115	40	111.67	126.21
	Gestating period (days)	Start	150	170		155	178	228	165	190	230	192	214	233
		Finish	264	284		269	292	342	279	304	344	311	329	347
	Aver. weight of sows at weaning in 2nd-4th litter (kg)[2,3]		60	165	220	75	183	220	70	176.5	197.5	70	182.5	210.25
	Lactating period (days)	Start	324	329		329	332	370	334	340	371	350	355	368
		Finish	1650	1480		1725	1594	1609	1720	1600	1566	1641	1467	1394
	Number of piglets/litter[1,3]		10	10.5	10	10.5	11	10.5	10.5	11	10.5	10.5	10.25	11.71
	Number of weaned pigs/litter[1,3]		9	9.5	9	9.5	10	9.5	9.5	10	9.5	9.5	9.75	10.68
	Birth weight/piglet[1,3]		0.5	0.72	1.1	0.5	0.8	1.2	0.5	0.85	1.25	0.5	1.15	1.46
	Weaning weight/pig[1,3]		7	10	7	7	9	7	7	10	7	6	7.08	6.62
	Number of days weaned[3]		60	42.5	30.5	57.5	42	28.5	51.25	37	27.5	38.75	29.94	25.64
	Number of litters/year[3]		1.77	1.85	1.95	1.82	1.91	1.95	1.94	1.98	2.08	1.95	2.17	2.19
	Farrowing interval (days)[2,3]		215	183	186	208	183	174	175	160.5	154.00	169.5	152.5	150.5
	Weight loss after weaning……kg[3]												40.00	26.12
	Weaning weight loss of sows (eq. to…% of BW)[3]												22.5	10.95
Central	First mating weight (kg)[2,3]		30	75	115	40	77.5	105	30	92.5	120	55	100	127.78
	Gestating period (days)	Start	150	180	245	155	178	228	165	190	230	184	193	231
		Finish	264	294	359	269	292	342	279	304	344	298	307	346
	Aver.weight of sows at weaning in 2nd-4th litter (kg)[2,3]		60	165	220	75	182.5	220	70	192.5	225	105	200	223.93
	Lactating period (days)	Start	324	334	387	329	332	370	334	340	371	331	293	357
		Finish	1655	1460	1463	1725	1594	1609	1720	1600	1566	1498	1476	1448
	Number of piglets/litter[1,3]		10	10.5	10	10.5	11	10.5	10.5	11	10.5	11.25	12.17	11.68
	Number of weaned pigs/litter[1,3]		9	9.5	9.00	9.5	10	9.5	9.5	10	9.5	10.25	10.58	10.73
	Birth weight/piglet[1,3]		0.5	0.72	1.1	0.5	0.8	1.2	0.5	0.85	1.25	0.85	1.17	1.48
	Weaning weight/pig[1,3]		7	10	7	7	9	7	7	10	7	5.5	6.75	6.69
	Number of days weaned[3]		60	42.5	30.5	57.5	41.75	28.5	55	39	27	35.67	31.17	24.72
	Number of litters/year[3]		1.77	1.90	2.00	1.81	1.89	1.95	1.85	1.91	2.05	1.97	2.13	2.21
	Farrowing interval (days)[2,3]		215	183	186	208	183	174	200	178.5	166	188.5	166	162
	Weight loss after weaning……kg[3]											25		29.88
	Weaning weight loss of sows (eq. to…% of BW)[3]											20		14.47

Region	Indicator	Period	1994-2000			2001-2010			2011-2020			2021-present		
			Local	Hybrid	Exotic	Local	Hybrid	Exotic	Local	Hybrid	Exotic	Local	Hybrid	Exotic
South	First mating weight (kg)[2,3]							105			112.5			123.53
	Gestating period (days)	Start						245			250			240
		Finish						359			365			354
	Aver. weight of sows at weaning in 2nd-4th litter (kg)[2,3]										220			225.66
	Lactating period (days)	Start						386			391			380
		Finish						1295			1361			1340
	Number of piglets/litter[1,3]		10	10.5	10	10.5	11	10.5	10.5	11	10.5	10.5	11	11.18
	Number of weaned pigs/litter[1,3]		9	9.5	9	9.5	10	9.5	9.5	10	9.5	9.5	10	10.02
	Birth weight/piglet[1,3]		0.5	0.72	1.1	0.5	0.8	1.2	0.5	0.85	1.25	0.5	0.9	1.35
	Weaning weight/pig[1,3]		7	10	7	7	9	7	7	10	7	6	7	7.15
	Number of days weaned[3]		60	50	33	60	45	28.5	60	42	27.25	35	35	25.85
	Number of litters/year[3]		1.84	1.8	1.9	1.84	1.82	2	1.90	1.85	2.08	1.9	2.1	2.21
	Farrowing interval (days)[2,3]							175			170.5			160
	Weight loss after weaning……kg[3]													18.5
	Weaning weight loss of sows (eq. to…% of BW)[3]													14.43

*BW: Boday weight; Data sources: 1: Expert judgment; 2: Focus group discussion (FGD); 3: Survey. *: 1994-2020: FGDs and 2021-present: FGDs and survey.*

Breed structure and percentages by farm-types

Table 4 summarizes the dynamics of pig breed composition (local, hybrid, exotic) and farm-type distribution (household vs. commercial) across four periods (1994–2000, 2001–2010, 2011–2020, and 2021–present), disaggregated by region. For 1994–2020, data were primarily derived from expert judgment and focus group discussions (FGDs), while survey data were incorporated in the most recent period (2021–present) to improve accuracy and standardization.

The data reveal a substantial structural shift in Vietnam's pig sector over time. Household-based production, which accounted for more than 90% of pigs in the 1990s, has declined to less than 30% in the most recent period, while commercial farms expanded to over 70%. Breed composition also shifted markedly: local breeds, which dominated in the 1990s (>50%), have nearly disappeared; hybrids peaked during 2001–2010 as transitional types; and exotic breeds now dominate, particularly in commercial systems where they represent 54–58% of pigs across all regions. Regionally, the South adopted commercial farming and exotic breeds earlier than the North and Central regions, but by 2021–present, commercial systems accounted for 72–73% of pig production nationwide, with exotic breeds as the predominant genetic resource.e.

Data reliability and implications for Tier 2 inventory

FGDs are generally regarded as providing a more precise representation of pig farming practices than expert judgment, as they gather firsthand accounts from livestock farmers. While survey data contribute valuable insights, their random sampling methodology may limit their representativeness compared to the targeted, in-depth discussions of FGDs.

Additionally, data reported to provincial management agencies, after aggregation and synthesis, offer a comprehensive and accurate reflection of the overall livestock structure at the provincial level.

To continuously monitor changes in farm-type structure, focus group discussions (FGDs) are the most suitable option due to their speed, cost-effectiveness, and close reflection of actual practices. FGDs are particularly useful when absolute figures are not required, but rather proportions, trends, and shifts between farming systems (households and commercial farms). A 3–5 years interval is considered appropriate, as it aligns with national greenhouse gas reporting cycles (BTR every 2 years, NDC every 5 years).

Regarding to breed structure data, in the recent period, survey data were collected under Decision No. 739/QD-TCTK (GSO, June 23, 2021), which established an official nationwide methodology for livestock data collection. These surveys are conducted quarterly (January 1, April 1, July 1, October 1), with reported figures reflecting the actual number of pigs in the preceding three months, ensuring timely and standardized reporting.

Table 4. Pig breed structure and percentage by farm type

Region	Farm-type / Period	Household				Commercial			
		Local	Hybrid	Exotic	Total	Local	Hybrid	Exotic	Total
North	1994-2000[1,2]	36.45	47.20	6.38	90,03	2.23	6.39	1.37	9,99
	2001-2010[1,2]	25.61	45.07	14.41	85,09	2.97	8.02	3.94	14,93
	2011-2020[1,2]	13.47	36.51	21.93	71,91	4.36	14.21	9.53	28,1
	2021-present[1,2,3]	2.75	12.09	12.27	27,11	1.81	17.08	54.00	72,89
Central	1994-2000[1,2]	56.45	35.01	3.56	95,02	2.23	2.33	0.43	4,99
	2001-2010[1,2]	29.99	46.79	9.56	86,34	3.59	7.55	2.53	13,67
	2011-2020[1,2]	14.26	36.57	25.58	76,41	3.57	10.40	9.63	23,6
	2021-present[1,2,3]	2.71	9.92	16.01	28,64	1.05	12.20	58.11	71,36
South	1994-2000[1,2]	55.89	39.15	0.00	95,04	1.45	3.03	0.48	4,96
	2001-2010[1,2]	17.97	24.52	38.84	81,33	1.10	3.07	14.50	18,67
	2011-2020[1,2]	8.40	19.93	41.84	70,17	0.76	2.47	26.62	29,85
	2021-present[1,2,3]	9.32	5.01	13.25	27,58	9.26	6.53	56.92	72,71

Data sources: 1: Expert judgment; 2: Focus group discussion (FGD); 3: Survey.

Feeding Practices and Intake

The percentage usage of feed types and feed intake are critical components of a Tier 2 livestock inventory, as they significantly impact the accuracy and representativeness of greenhouse gas (GHG) emission estimates.

Percentage usage of feed types provides a realistic assessment of how different feed sources are utilized within the national livestock sector. This is essential because each feed type has distinct emission factors that influence GHG calculations.

Feed intake directly affects manure volume and composition, influencing methane (CH_4) and nitrous oxide (N_2O) emissions during storage and handling. Accurate feed intake data enables the development of precise emission factors tailored to country-specific conditions.

Table 5 and table 6 present data from 278 farming facilities across six provinces, representing the country's three regions and two primary farming systems. These data sources provide insights into: The percentage usage of different feed types; Feed intake measurements at various pig growing stages.

In Vietnam, four common feed types were identified: (1) Industrial complete feed; (2) Self-mixed complete feed; (3) Concentrated feed; and (4) On-farm residual feeds

The dry matter percentage (DM%) were derived from expert adjustment. This detailed data collection aligns with the Tier 2 inventory requirements, which necessitate country-specific information on feed intake rates by pig growth stage.

Data reliability and implications for Tier 2 inventory

Collecting feed parameters through surveys ensures greater precision by directly engaging with farmers to gather detailed information on specific feed utilization practices, on-farm mixing techniques, and utilization of local feed resources.

This farm-level insight allows for a more accurate quantification of regional variations in feed availability and usage, which is critical for developing country-specific emission factors.

Given that feeding practices are heavily influenced by breed structure and farming systems, surveys should be conducted at least every five years to ensure data remains up to date and reflective of industry changes. Regular data collection will help refine GHG emission calculations, supporting Vietnam's commitment to improving livestock sector sustainability.

Table 5. Types of feed in household farms by breed and pig growth stage

Region	Breed	Local					Hybrid					Exotic				
	Sub-category / Feed	Weaning	Growing	Fattening	Gestating	Lactating	Weaning	Growing	Fattening	Gestating	Lactating	Weaning	Growing	Fattening	Gestating	Lactating
North	1. Industrial complete feed (%)	100	50	50	50	33.33	82.35	63.64	55	50	56.25	86.67	93.33	81.25	50	87.5
	…….. kg/head/day	0.2	0.5	1	5.5	5	0.73	1.32	2.41	2.26	4.28	0.69	1.92	2.78	2.14	5.26
	2. Self-mixed complete feed (%)														5.56	6.25
	…….. kg/head/day														2.5	4
	3. Concentrated feed (%)								5			6.67		6.25		
	…….. kg/head/day								1.7			0.18		0.35		
	4. Other (%)		50	50	50	66.67	17.65	36.36	40	50	43.75	6.67	6.67	12.5	44.44	6.25
	…….. kg/head/day		5	5	5.5	3.85	0.17	2.31	2.94	3.68	4.71	6	8	6	3.54	5.5
Central	1. Industrial complete feed (%)	66.67	100	100	20	40	89.74	87.5	87.18	41.03	42.86	100	83.33	90.91	63.64	75
	…….. kg/head/day	0.45	2	1.95	0.4	3.5	0.7	1.45	1.98	1.66	3.12	0.59	1.73	2.52	1.93	4
	2. Self-mixed complete feed (%)							2.5	2.56	10.26	9.52				9.09	8.33
	…….. kg/head/day							1	1	1.88	3.38				2	3
	3. Concentrated feed (%)															
	…….. kg/head/day															
	4. Other (%)	33.33			80	60	10.26	10	10.26	48.72	47.62		16.67	9.09	27.27	16.67
	…….. kg/head/day	0.3			3.5	3	0.45	1.38	2.03	2.19	3.21		2.5	3	3	3
South	1. Industrial complete feed (%)	100	100	100			50	50	100	50	100	100	100	100	100	100
	…….. kg/head/day	0.66	1.48	2.61			0.65	1.45	2.33	2.3	3	0.58	1.69	2.64	2.3	4.89
	2. Self-mixed complete feed (%)															
	…….. kg/head/day															
	3. Concentrated feed (%)															
	…….. kg/head/day															
	4. Other (%)						50	50		50						
	…….. kg/head/day						0.6	2		3						

Table 6. Types of feed in commercial farms by breed and pig growth stage

Region	Breed	Local					Hybrid					Exotic				
	Feed \ Sub-category	Weaning	Growing	Fattening	Gestating	Lactating	Weaning	Growing	Fattening	Gestating	Lactating	Weaning	Growing	Fattening	Gestating	Lactating
North	1. Industrial complete feed (%)						75	75	75	75	75	97.84	97.84	95.81	80.35	88.35
	…….. kg/head/day						0.73		2.5	2.5	4.17	0.73	2.16	2.68	2.24	5.04
	2. Self-mixed complete feed (%)															2.33
	…….. kg/head/day															4.2
	3. Concentrated feed (%)															
	…….. kg/head/day															
	4. Other (%)						25	25	25	25	25	2.16	2.16	4.19	17.37	16.05
	…….. kg/head/day						1		3	4	5	1	1	2.3	2.5	4.75
Central	1. Industrial complete feed (%)						87.5	100	100	67.5	80.17	100	98.65	98.65	92.75	95.09
	…….. kg/head/day						0.65		1.9	2.06	3.47	0.6	1.82	2.67	2.18	4.75
	2. Self-mixed complete feed (%)										13.22				2.9	1.6
	…….. kg/head/day										5.15				2.05	2.5
	3. Concentrated feed (%)															
	…….. kg/head/day															
	4. Other (%)						12.5			32.5	6.61		1.35	1.35	4.35	3.31
	…….. kg/head/day						1			2	2		0.4	0.6	1.7	3.5
South	1. Industrial complete feed (%)											98.71	98.71	96.10	93.73	93.73
	…….. kg/head/day											0.63	1.5	1.6	2.39	4.75
	2. Self-mixed complete feed (%)											1.29	1.29	3.90	6.27	6,27
	…….. kg/head/day											0.55	1.6	2.5	2.4	4.25
	3. Concentrated feed (%)						75	75	75	75	75	97.84	97.84	95.81	80.35	88.35
	…….. kg/head/day						0.73		2.5	2.5	4.17	0.73	2.16	2.68	2.24	5.04
	4. Other (%)															2.33
	…….. kg/head/day															4.2

Manure management

To determine the proportions of manure management systems, data were collected from expert judgment, focus group discussions (FGDs), and surveys, as summarized in Table 7. These data sources provide insights into shifting trends in manure management practices across different time periods, farm types, and regions.

A clear shift in manure management practices is evident in household farms. While solid storage was the dominant method in earlier periods, its usage has steadily declined. In contrast, biogas adoption has significantly increased, reflecting growing interest in sustainable waste management solutions. Initially (1994–2000), biogas usage was relatively low, ranging from 2.5% to 17.5% across different regions. In the most recent period (2021–present), biogas adoption has risen dramatically, with the national average reaching approximately 62%. This shift highlights increased awareness and investment in biogas technology, likely driven by government incentives, technological advancements, and environmental concerns. In terms of commercial farms, they adopted biogas systems earlier than household farms, with utilization rates reaching 50% in both the North and South regions as early as 1994–2000. Over subsequent periods, biogas adoption continued to grow, while the most recent data indicate a diversification of manure management strategies, with composting and lagoon systems gaining popularity and reflecting a more integrated approach in commercial farms.

Data reliability and implications for Tier 2 inventory

Throughout all time periods, significant discrepancies were observed between expert judgment and FGD data. However, in the most recent period, survey data aligned more closely with FGD findings, suggesting that FGDs provide an accurate representation of contemporary manure management practices. Consequently, FGDs can be considered a reliable data source for estimating manure management proportions

To enhance the accuracy and consistency of data for Tier 2 inventory updates, FGDs should be conducted whenever farming systems change to capture shifts in manure management trends.

Monitoring should also consider regulatory changes, as government policies can accelerate the transition to more sustainable waste management solutions.

Table 7. Manure management in different system

Farm-type	Period	Region	Biogas	Covered anaerobic lagoon	Uncovered anaerobic lagoon	Aerobic treatment - nature aeration systems	Solid storage	Pasture/range/ paddock	Compost	Daily spread	Other
Household	2021-present[1,2,3]	North	56.3	1.7	0.0	4.7	19.4	10.7	2.7	2.5	2.2
		Central	67.3	0.4	0.0	1.9	16.4	9.8	1.1	2.5	0.6
		South	67.8	0.4	0.0	4.1	14.9	8.3	1.0	1.7	1.8
	2011-2020[1,2]	North	47.5	0	0	2.5	35	12.5	0	2.5	0
		Central	55	0	0	3.75	28.75	10	0	2.5	0
		South	47.5	0	0	11.75	28.25	10	0	2.5	0
	2001-2010[1,2]	North	20	0	0	5	60	12.5	0	2.5	0
		Central	10	3.75	0	11.25	42.5	8.75	21.25	2.5	0
		South	40	0	15	0	35	7.5	0	2.5	0
	1994-2000[1,2]	North	2.5	0	0	0	85	7.5	0	5	0
		Central	3.75	0	0	12.5	72.5	6.25	0	5	0
		South	17.5	0	35	0	40	2.5	0	5	0
Commercial	2021-present[1,2,3]	North	65.58	2.21	3.33	4.63	15.96	3.33	3.17	1.36	0.42
		Central	68.60	0.13	3.41	2.02	17.27	3.33	2.38	2.54	0.33
		South	72.82	0.36	3.33	0.76	14.26	3.33	2.33	1.00	1.79
	2011-2020[1,2]	North	66.75	0	2.5	2.5	18.25	5	2.5	2.5	0
		Central	69.2	0	2.5	0	18.3	5	2.5	2.5	0
		South	69.88	0.00	2.50	0.00	17.63	5.00	2.50	2.50	0.00
	2001-2010[1,2]	North	48.2	0	0	4	40.3	5	2.5	0	0
		Central	45	0	0	2.5	43.5	6.5	2.5	0	0
		South	67.5	0	0	0	25	5	2.5	0	0
	1994-2000[1,2]	North	50	0	0	0	40	5	0	5	0
		Central	7.5	0	0	7.5	72.5	7.5	0	5	0
		South	55	0	0	0	35	5	0	5	0

Data sources: 1: Expert judgment; 2: Focus group discussion (FGD); 3: Survey.

Conclusions and recommendations

Conclusions

This study addressed critical data gaps for developing Tier 2 greenhouse gas (GHG) inventories of pig production in Vietnam. By combining farm surveys, focus group discussions, and expert consultations, it generated country-specific data on pig population structure, reproductive performance, growth rates, feed intake, and manure management across four time periods. Results demonstrated that survey data provide the most reliable basis for quantitative parameters, while expert judgment and focus groups add value in reconstructing historical trends and validating management practices.

A key finding is the heterogeneity of manure management systems, with smallholder reliance on lagoons and direct discharge leading to higher methane and nitrous oxide emissions, while commercial adoption of biogas and controlled storage offers mitigation opportunities. Integrating these system-specific distributions into Tier 2 inventories significantly improves accuracy and reduces uncertainty compared to Tier 1.

Recommendations

Based on these findings, the following data collection cycles are recommended:

Every 3–5 years: pig growth stages, sow productivity, breed structure, farm-type distribution, and manure management.

Every 5 years: feed intake and feed composition.

Event-based updates: immediate revisions when major changes occur in farming systems, particularly for manure management.

In the long term, collaboration between research institutions and government agencies should be strengthened to ensure transparent and regularly updated inventories for policy use.

Additionally, for GHG mitigation, the adoption and proper maintenance of biogas digesters should be promoted, together with improved composting and field application practices.

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