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Abstract
This study aims to determine the current status of manure management of pig farms in Gia Kiem commune, Thong Nhat district, Dong Nai province. Information was collected on 30 pig farms by using a standardized questionnaire. Waste of pigs on surveyed farms included two different types: (i) solid waste (feces) and (ii) slurry, i.e. a mixture of feces, urine and flushing water. On 67% of farms the slurry was stored. When stored, 65% of it was used for the production of biogas through anaerobic digestion (AD). The digestate was used as a fertilizer for crops or discharged directly into the environment. The remaining 35% of farms stored the slurry in ponds nearby. Solid waste was collected actively, yielding 609 kg fresh weight of solids per farm per day, on average. Most of it (87%) was traded by middle men and transported to growers elsewhere. Farmers considered the lack of processing capacity (composting, anaerobic digestion, separation into liquids and solids), lack of transport capacity, absence of information regarding manure management improvements, absence of interest in manure management, and lack of access to loans for building manure management systems to be the most important factors discouraging the use of manure as fertilizer. Socio-economic constraints do not really hinder the decision to use manure as fertilizer on the farms. The major reason to improve manure management is that wastes are having a direct impact on the health of humans andanimals, and on water quality and odor emissions to residential areas.

Keywords: manure, management, pig farming, slurry, solids, anaerobic digestion

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1. Introduction

Pig production in Vietnam is rapidly shifting from small-scale holdings in backyards to intensive farms in order to meet the growing food demands of consumers. The intensification of farming systems led to considerable economic benefits. However, it has also caused serious environmental pollution resulting from the associated production of manure. Adequate management of manure (i.e. the eventual sum of feces, urine, flushing water, bedding material and spilled feed) is decisive for a sustainable development of pig production. The management of manure pertains to all potential human activities following the excretion of urine and feces of livestock: its collection, storage, treatment, transport and application to land. Wherever manure is discharged to surface water or into landfills instead of being used as fertilizer, manure management falls short. Poor management has implications for the utilization of the resources that manures contain (N, P, K and C) and for detrimental emissions (GHG, NH_3, NO_3, P, organic compounds, pathogens, odour,…) to air and water.

An accurate picture of the current waste management situation is needed to assess which concrete actions are needed to improve the environmental performance of pig farming. A survey was initiated to get that picture for pig farms in Gia Kiem commune, Thong Nhat district, Dong Nai province, Vietnam.

2. Materials and methods

2.1 General survey

The present study consisted of two parts: (i) a general survey and (ii) an in-depth survey. The general survey was aimed at characterizing the Thong Nhat district in terms of its agriculture in general and livestock production in particular. The general survey can be looked upon as an ex-post justification of our focus on the pig production in the Gia Kiem commune in the in-depth survey, as it shows that pig production is the dominant form of livestock production there. Both surveys were executed from October to December 2013. The general survey was conducted by collecting data from the department of agriculture and the department of statistics of Thong Nhat district, Dong Nai province. The collected information characterizes the agricultural production in the region, the dominant farming system, the number of farms and the type and number of animals.

2.2 Characteristics of the surveyed area

Thong Nhat district represents just a minor fraction of the Vietnamese total land area and population. This holds, of course, even more for the Gia Kiem commune and hamlets within that commune, as illustrated in Table 1.This implies that our conclusions cannot be extrapolated to Vietnam as a whole.

Table 1: The area and population represented while zooming-in into the eventual delineations of the in-depth survey

Unit:		Country:	Province:	District:	Commune:	Hamlets:
		Vietnam	*Dong Nai*	*Thong Nhat*	*Gia Kiem*	*Vo Dong 1 & 3*
Total area	(km^2)	331000	5862	247	33.4	17.7
Agricultural area	(km^2)	109000	2776	207	25	15.2
Total population	*1000	92478	2720	158	24	7.7
Urban population	%	32	34	34	0	0
Population working in agriculture	%	68	66	60	100	100

Thong Nhat district belongs to Dong Nai province which is located in the South East of Vietnam. In the north, Thong Nhat borders to Lam Dong and Binh Duong provinces, in the east to Binh Thuan, and to Ba Ria - Vung Tau provinces and to Hochiminh City in the south. The urban population percentage is 34%, the percentage of people working in agriculture amounts to 60%.

Thong Nhat has 11 administrative units: Gia Tan 1, Gia Tan 2, Gia Tan 3, Gia Kiem, Quang Trung, Bau Ham 2, Xa Lo 25, Hung Loc, Xuan Thien, Xuan Thanh and Dau Giay town. The total natural area of the district is 24,724 ha with a population of 157,980 people. The area measures 20,726 hectares of agricultural land, of which 20,155 hectares of arable land, 1,262 hectares of vegetables, 322 hectares of other crops and 125 hectares of fisheries. The total annual rice output in the district was 14,800 tons, the annual corn output was 18,170 tons, the total area of annual crops is only about 8400 hectares, so the average grain yield is about 3,9 tons per hectare.

Thong Nhat is located in the tropical climate zone, implying that it is generally sunny (2600-2700 hours/year) and hot (temperature during the year averaging 25 - 26°C, with a minimum of 21 - 22°C and a maximum of 34 - 35°C). Consequently, the total cumulated temperature is also high (average 9,490°C). The annual rainfall of Thong Nhat is considerable (2,139 mm), and it has a profound seasonal distribution with a rainy season from May to October (with 85-90% of the annual rainfall occurring in these 6 months) and a dry season from November to April. Monthly temperatures and rainfall for the Dong Nai province as a whole are shown in Table 2.

Table 2: Averge temperature and rainfall in Dong Nai

Months	1	2	3	4	5	6	7	8	9	10	11	12
The average temperature (°C)	25.5	26.3	27.6	27.3	27.0	26.5	25.9	26.6	25.4	26.2	26.7	26.2
Rainfall (mm)	9	38	68	313	263	274	494	203	599	129	34	8

Source: Bureau of Statistics Dong Nai , 2012

Dong Nai is the leading province in Vietnam concerning the industrialization of pig and chicken production. Within Dong Nai, Thong Nhat is the most developed district in this respect, and Gia Kiem commune is the nucleus of pig production in Dong Nai since 1954. The number of pigs per capita of the commune and the district exceeds those of the province and the country as well (Vietnam 0.28, Dong Nai 0.48, Thong Nhat 1.02 and Gia Kiem 2.32. According to the planned orientation, Dong Nai province is meant to become one of the major districts for industrial animal production. Presently, the district has a total of 659 livestock farms (farms being defined as an enterprise with a yearly turnover ≥ 1 billion VND). In view of the above, Gia Kiem was chosen for the in-depth survey. The consequential difficulties and constraints in manure management represent a hot issue, not only for pig farmers but also for local authorities and community. This issue needs to be addressed shortly.

According to the statistics of the Thong Nhat district, the total livestock population in September 2013 amounted to 210,000 pigs, 950,000 chickens, 5271 ducks, approximately 1.4 million quail chicken, 2,615 cattle and 2,390 goats. These numbers are greater than the total values in Table 3, because these values do not include the animals that farms keep for companies on the basis of contracts. This implies that the total manure production is approximately 50% greater than suggested by the animal numbers given in Table 3. In the Thong Nhat district, the major livestock production system is swine production including both sows and fattening pigs. Field observations in the five communes along the National Highway 20 (Quang Trung, Gia Kiem, Gia Tan 1, Gia Tan 2 and Gia Tan 3) confirmed that the major part of the livestock production concerns sows and pigs. This includes both small scale holdings in backyards and the more industrial holdings. We therefore selected Gia Kiem to conduct an in-depth survey on the current status of pig manure management.

Table 3: Number of animal heads in different communes in Thong Nhat district (not including the animals that are kept for companies on the basis of contracts)

Commune	Pigs, total	Fattening pigs	Sows	Boars	Broilers	Laying hens	Quail
Gia Kiem	55,722	47,213	8,403	106	40,000	-	-
Gia Tan 3	28,910	25,780	3,130	-	47,000	12,000	170,000
Gia Tan 2	23,887	20,857	3,016	14	295,000	-	15,000
Hung Loc	21,593	21,593	-	-	-	-	-
Xa Lo 25	18,873	18,402	471	-	-	-	-
Quang Trung	15,445	12,734	2,711	-	30,000	-	-
Gia Tan 1	3,787	3,215	568	4	-	-	-
Xuan Thien	3,553	3,368	185	-	169,000	-	60,000
Xuan Thanh	2,655	2,433	222	-	375	59	-
Bau Ham 2	1423	1274	149	-	100	20	-
Total = Thong Nhat district	175,848	156,869	18,855	124	581,475	12,079	260,000

Source: Department of Agriculture and Rural Development of Thong Nhat district, 2013

2.3 In-depth survey

The in-depth survey was conducted on 30 more or less industrialized pig farms in the Gia Kiem commune, Thong Nhat district, Dong Nai province. The farms were randomly selected from a list of 265 pig farms of two hamlets Vo Dong 1 and Vo Dong 3 of the Gia Kiem commune. The information on manure management was based on the answers of farmers to a standardized questionnaire. A draft questionnaire was tested on 4 pig farms beforehand, with the aim to remove ambiguities and to add omissions. The results of this test were used to modify the questionnaire before conducting the formal in-depth survey in the other 26 farms. The questionnaire consisted of the following main components: information on the farm's resources (labor, land, education of the farm head), characterization of the farming system and livestock productivity, characteristics of pig production systems (feeding, housing, marketing), the current status of manure management, and the constraints and limitations in the management and use of pig manure.

2.4 2.4. Data processing

The data were analyzed by software Minitab version 14. The average value and standard deviation are shown.

3. Results and discussion

3.1 Resources of the survey farm

Labor and land are two important factors that determine the available options for manure management. These resources generally provide the basis for the farm owners to choose appropriate modes of production (Raquel 1985; Baker 1997; Nelson & Cramb 1998; Savadogo et al. 1998). The number of laborers and land of the farms are shown in Table 4.

Table 4: Labor and farm land

Criteria	n	Average	Standard deviation	Smallest* 6 farms	Intermediate 18 farms	Largest* 6 farms
Number of family members (people)	30	5.3	1.3	5.3	5.2	5.5
Male	30	2.6	1.3	3.0	2.3	3.5
Female	30	2.7	1.1	2.5	2.8	2.0
Number of persons <16 years old (people)	30	1.2	1.0	1.8	0.9	1.5
Number of potentially available laborers (person)	30	2.7	1.3	1.7	2.6	4.1
Current labor hours (hours/person/day)	30	5.3	1.9	3.7	5.1	7.3
Number of laborers working entirely elsewhere (person)	30	0.8	1.2	0.7	0.6	1.5
The total area of agricultural land (ha)	30	1.5	2.6	0.2	1,8	2.5
The total land area for horticulture (ha)	30	1.3	2.6	0.2	1.5	2.2
Distance from farm to town (km)	30	1.81	0.1	1.7	1.7	2.2

*Small and large refer to the number of pigs (fattening pigs and sows) per farm

Table 4 shows that a household included 5.3 persons, on average. There was a slight difference between smallest, intermediate and largest farms in terms of the number of family members. The proportion of each gender was around 50%. The number of laborers accounted for approximately 50% of the household members. About 70% of the potentially available laborers participate in farm production and the remaining 30% laborers earn a living elsewhere. Every laborer that is mainly working on the farm carries out about 5.3 hours of work per day.

The availability of land does not only provide pig farmers with additional options to produce food and feed, but is also determining options for manure management in terms of available spreadlands for manure. With landless farms manure is at best sold to middle men who transport and sell it to remote crop growers. However, manure is in many cases rather discharged directly into the environment than used for crop production. The survey showed that every farm has, on average, about 1.5 hectares of land for agricultural production, of which 87% is used for horticulture. This means that land is not in the least bit used to sustain livestock with home-produced feed. Note, that there is great variation in the area of agricultural land between farms (coefficient of variation = 174%). There were five farms out of 30 that did not have any agricultural land at all. The smallest farms have around 0.2 hectares while it is 2.5 hectares for the largest farms.

The distance from the farm to the nearest town has significance in terms of demand for livestock products exerted by consumers, the competition with alternative forms of employment in these towns, as well as availability of suitable manure management solutions. The survey showed that most of the pig farms are not far from the nearest town, just about 1.8 km. Large farms are a bit further from the nearest town, 2.2 km.

Education is one of indicators of the labor quality. When educated at a higher level, farm owners tend to easily accept and apply more advanced technologies (Feder & Umali, 1993; Feder et al., 1985). The survey showed that 90% of all farm owners had secondary education or higher, the remaining 10% had received primary education only.

3.2 Characteristics of pig production systems

The type of pig production system (size, herd structure, productivity, feed, housing, etc) also is an important determinant of manure management and, hence, the level of environmental pollution.

Table 5: Herd structure at the time of the survey

	Average	**Standard Deviation**	**Smallest* 6 farms**	**Intermediate 18 farms**	**Largest* 6 farms**
Total pigs (heads/farm)	279.3	320.3	62.2	185.9	776.7
Number of pigs > 20 kg (heads/farm)	172.3	183.4	38.3	113.3	483.3
Average pig weight (kg)	51.5	6.8	48.3	51.9	53.3
Number of sows (heads/farm)	33.0	40.2	8.0	21.2	93.3
Average sow live weight (kg)	156.0	8.6	169.2	153.1	151.7
Number of piglets < 20 kg (heads/farm)	74.0	111.3	15.8	51.4	200.0
Average piglet weight (kg)	9.5	1.5	9.8	9.7	8.5

*small and large refer to the number of pigs (fattening pigs and sows) per farm

Livestock production scale

The survey showed that all farms are specialized in raising pigs with an average presence of 279 pigs. There is a huge difference in terms of total number of pigs per farm. Numbers amounted to 62, 186 and 777 for the 6 smallest, the 18 intermediate and the 6 largest farms, respectively. Fattening pigs (weight > 20 kg) accounted for about 62% to the total number, piglets (< 20 kg) for approximately 27%, and sows for the remaining 12% (Table 5). None of the farms kept boars due to the adoption of artificial insemination. Semen was bought from the breeding center or from farms specialized in selling pig semen.

Livestock productivity

Pig productivity in 2012 is shown in Table 6. The survey showed that the average annual output per farm is about 540 heads. This means that there are, on average, 1.93 rounds per year. A large difference in terms of the annual number of slaughtered pigs per farm was observed. This number amounted to 135, 337 and 1431 pigs on the smallest, intermediate and largest farms, respectively. Note that there appears to be a negative trend between the size of a farm and the number of rounds per year. It ranged from, on average, 2.17 for the smallest farms, 2.03 for intermediate farms and 1.84 for the largest farms, although slaughter ages were slightly higher on the smallest farms. The average slaughter age was roundabout 6 months at an average body weight of around 100 kg per head. Besides, every farm produced 618 weaned piglets per year. The number of weaned piglets per sow was 19, the average weaning weight was 7.2 kg per head. There is vast variation in the number of fattened pigs as well as the number of weaned pigs between farms. This is reflected in the magnitude of the standard deviation.

Table 6: Pig productivities in 2012

Criteria	Average	Standard Deviation	Smallest* 6 farms	Intermediate 18 farms	Largest* 6 farms
Number of slaughtered pigs /farm/year (heads)	539.5	573.6	135.0	377.2	1430.8
Slaughter weight (kg)	101.5	3.3	101.7	101.7	100.8
Slaughter age (months)	6.2	0.4	6.3	6.2	6.0
Number of weaned piglets/farm/year (heads)	617.6	766.5	150.0	395.4	1751.7
Number of weaned piglets/sow/year (heads)	18.6	1.4	18.8	18.4	18.7
Weaning weight (kg)	7.2	1.5	7.6	6.9	7.2

*small and large refer to the number of pigs (fattening pigs and sows) per farm

Consumption of livestock products

Pigs and piglets are the two major products of the farm. The survey results showed that 77% of the farms are keeping sows to produce weaned piglets and use these for raising fattening pigs to be sold to the market. The remaining 23% of the farms used 78% of their weaned piglets for raising fattening pigs and sold the remainder (22%). These are the common characteristics of intensive pig farms in Vietnam.

Feed and nutrition

All farmers use compound feed for their piglets, fattening pigs and sows. Choices concerning the composition of the feed depend on the growth period and the specific sexual maturity. Compound feed is generally purchased from feed companies such as CP, Proconco, GreenFeed, etcetera. Some farmers mix the feed themselves from local ingredients to save costs. A growing pig (weight > 20 kg/head) consumed on average 2.4 (ranging from 2.34 to 2.49) kg feed per day. Piglets (weight < 20 kg/head) consumed 0.36 (range 0.31-0.39) kg and sows 2.9 (ranging from 2.8 to 2.95) kg feed per day.

Pig housing and livestock manure collection system

The pig housing system has an important influence on manure management procedures. All the farms had fences or walls, had concrete floors and were roofed. There were special sections for sows, for fattening pigs and for piglets. All farms derive the drinking water and flushing water for their livestock from groundwater wells. Fresh solid manure (feces and, potentially, some spilled feed) is collected directly on a daily basis and put into bags (waterproof bags in which the compound feed had been delivered). After collection of these solids, the floors are usually flushed. This takes place once a day in the dry season but a few times per day in the rainy season. The combined slurry-like mass of flushing water, urine, fecal residues and scattered feed, is directed via cement trenches to biogas pits, to nearby reservoirs, or directly discharged into the environment. This type of handling is supportive to industrial pig production and, as such, typical although not necessarily environmentally friendly.

The average pig farm measures an area of about 1,750 square meters. There is, however, a large variation between farms (coefficient of variation is about 130%). This is logical because there is also a considerable variation in size between farms (Table 4). The major part of the area is devoted to the production of fattening pig. It accounts for 89%. On average, each pig had an average area of approximately 9 square meters (Table 7). Note that the area per individual pig tends to be much smaller on large farms than on small farms. It is important to know that some pig cages of the farms were not used for raising pigs at the time of conducting the survey due to low slaughtering prices in 2012.

Table 7: Area for pig keeping of the surveyed farms

Criteria	n	Average	Standard Deviation	Smallest* 6 farms	Intermediate 18 farms	Largest* 6 farms
Total pig farm area (m^2)	30	1,750.8	2,265.2	786.7	1544.7	3333.3
Sow area (m^2)	30	186.4	231.9	46.3	124.7	511.7
Fattening pig area (m^2)	30	1,564.4	2,097.8	740.3	1419.9	2821.7
Barn area/fattening pig (m^2)	30	9.6	11.0	17.3	9.1	3.3
Barn area/pig (m^2)	30	8.9	8.8	14.6	8.7	3.6

** small and large refer to the number of pigs (fattening pigs and sows) per farm*

3.3 Current status of manure management in pig farms

Type of manure

Depending on the manure collection and processing system, the housing system, and the eventual destination of the manure, three different types of manure could be discerned: (i) solid manure (feces), (ii) a mixture of urine and flushing water, and (iii) a mixture of urine, flushing water and (some) solid manure (slurry). The survey results showed that 100% of the surveyed farms collect solid waste actively. Most farmers sold this fresh solid manure to middlemen at a price of 5,000 VND per bag (about 30 kg). The demand for solid pig manure is good in the dry season, but is limited in the rainy months. Most of manure is transported straightly to Lam Dong province to be used as fertilizer on crops such as coffee and tea.

The separated collection of solids and liquid fractions can have a great environmental significance. Results from some authors showed that this type of separation is able to reduce the emission of NH_3 and other odorous gases (Aarnink & Ogink, 2008). Consequently, in view of these environmental aspects, this is a form of manure management that is to be considered. However, if separation implies that just one of the two fractions (i.e. the solids) receives economic and environmental attention and the other less valuable fraction (i.e. the liquid) is discarded, this type of manure management may yet require re-thinking.

As far as the population of pig farms in this survey was concerned, none of the farms collected and stored urine (or mixtures of urine and flushing water) separately. If collected, as was the case for 67% of the farms, collection and storage always involved the combined collection of a slurry comprising a mixture of urine, fecal residues, flushing water and scattered feeds. Of the 67% of the farms that collected this slurry, 65% stored it for use in a biogas system and 35% stored it in nearby pits. The excess water of pits was emptied passively by running into the cannels, rivers and streams. The average volume of the anaerobic digestion (AD, 'biogas') systems was 9.7 m^3 per farm (minimum 4.5 m^3 and maximum 14 m^3), and the average volume of pits amounted to 28.1 m^3 per farm (minimum 10 m^3 and maximum 50 m^3). Thus, the surveyed pig farms appear to have two main types of farm 'wastes': (i) solids and (ii) a slurry-like mixture of feces, urine, flushing water and scattered feeds (slurry).

In tropical countries, flushing water entails a large proportion of the total amount of waste from pigs. The survey results showed that 100% of the farms used groundwater wells for cleaning cages. On average, each farm used 6,975 liters of water per day, but there were wide variations between farms (106% coefficient of variation). On average, each farm used 35 liters of water per growing pig and sow per day. This amount pertains to the sum of drinking water and flushing water. None of the surveyed farms used bedding material. Consequently, the slurries consisted of pig feces, urine, flushing water and scattered feeds.

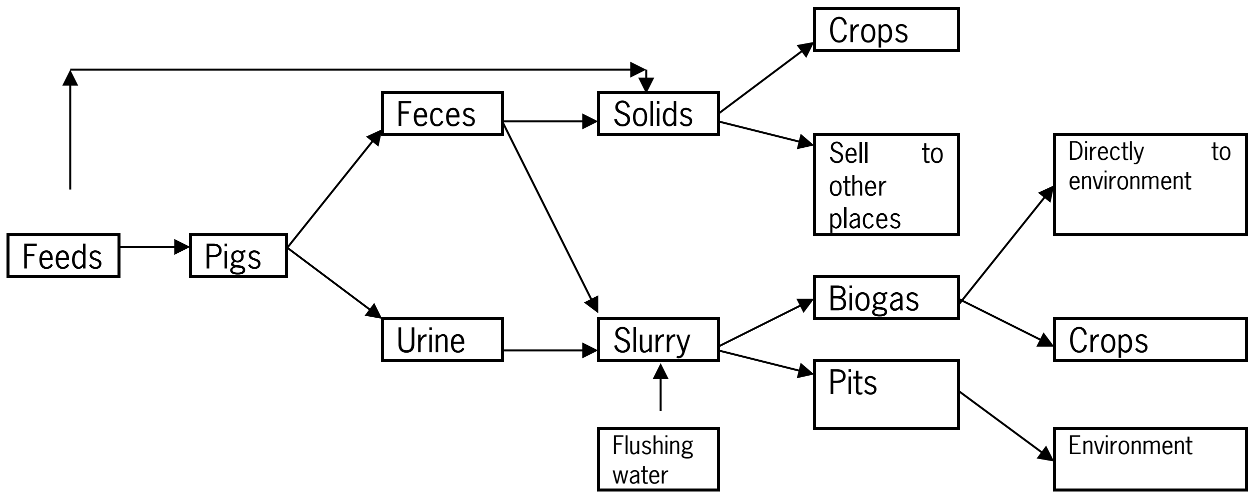

Figure 1: Manure forms and flows of solids and liquids

Solid and liquid (slurry) flows across farms were quite similar. The type of manure and manure flows are qualitatively pictured in Figure 1. Thirteen of the 20 farms stored slurry and used their slurry mixture to produce biogas via AD. Of the remaining 7 farms, 1 used the slurry directly as a fertilizer for corps, whereas the other 6 kept in a pit but its liquids gradually emptied passively into the environment. The digestate that was produced by the 13 farms with AD, was used as fertilizer for plants on 10 farms but directly discharged to the environment by the 3 other farms.
Solid waste (feces) was collected directly and actively. On average, each farm collected 609 kg fresh weight of solid manure per day. There is, however, a great variation in the amount of collected solids (117% coefficient of variation). This is logical because there is great variation in the number of pigs per livestock farm (Table 2). After collecting, 17% of solid manure was used directly as a fertilizer for local crops. Most of it (83%) was sold to stockless farms where it is used as a fertilizer. The demand for this type of fertilizer comes from places as far as the Central Highlands of Vietnam.

Figure 2: The herd-size weighted distribution of manure-N and manure-P_2O_5 over solids and liquids (slurries) and their eventual destinations

	farms:		**heads:**			**kg N/yr:***			**kg P2O5/yr:***		
	absolute	(%)	per farm	per subgroup		per farm	per subgroup		per farm	per subgroup	
				absolute	%		absolute	%		absolute	%
1. All	30	(100)	279	8370	(100)	2790	83700	(100)	1116	33480	(100)
1.1 Farms with slurry only	0	(0)	n.a.	0	(0)	n.a.	0	(0)	n.a.	0	(0)
1.2 Farms with separation	30	(100)	279	8370	(100)	2790	83700	(100)	1116	33480	(100)
1.2.1 of which solids	30	(100)	279	8370	(100)	837	25110	(30)	1004	30132	(90)
1.2.1.1 of which solids applied to nearby land	*2*	*(7)*	*108*	*216*	*(2)*	*324*	*648*	*(1)*	*389*	*778*	*(2)*
1.2.1.2 of which solids applied to remote land	*20*	*(67)*	*272*	*5440*	*(65)*	*816*	*16320*	*(19)*	*979*	*19584*	*(58)*
1.2.1.3 of which solids applied to both	*8*	*(26)*	*350*	*2800*	*(33)*	*1050*	*8400*	*(10)*	*1260*	*10080*	*(30)*
1.2.2 of which liquids (slurry)	30	(100)	279	8370	(100)	1953	58590	(70)	112	3348	(10)
1.2.2.1 of which dicharged directly into environment	*9*	*(30)*	*509*	*4581*	*(55)*	*3563*	*32067*	*(38)*	*204*	*1832*	*(6)*
1.2.2.2 of which directly applied to land	*1*	*(3)*	*136*	*136*	*(2)*	*952*	*952*	*(1)*	*54*	*54*	*(0)*
1.2.2.3 of which collected for further handling	*20*	*(67)*	*183*	*3660*	*(43)*	*1281*	*25620*	*(31)*	*73*	*1464*	*(4)*
1.2.2.3.1 of which anaerobically digested**	13	(43)	175	2275	(27)	1225	15925	(19)	70	910	(3)
1.2.2.3.2 of which not anaerobically digested	7	(23)	197	1379	(16)	1379	9653	(12)	79	552	(1)
anaerobically digested:											
1.2.2.3.1.1 afterwards applied to land	10	(33)	150	1500	(18)	1050	10500	(13)	60	600	(2)
1.2.2.3.1.2 afterwards dicharged into environment	3	(10)	262	786	(9)	1834	5502	(6)	105	314	(1)
not anaerobically digested:											
1.2.2.3.2.1 applied to land	1	(3)	180	180	(2)	1260	1260	(2)	72	72	(0)
1.2.2.3.2.2 unknown***	6	(20)	171	1026	(12)	1197	7182	(9)	68	410	(1)
Percentage of manure utilized as fertilizer								(<46)			(92)

**assuming that a pig excretes 10 kg N per year of which 3 kg in solids and 4 kg P_2O_5 per year of which 3.6 kg in solids (after Canh et al. (1997), Abioye et al. (2010) and Van der Peet-Schwering et al. (1999) and Jörgensen et al. (2013))*

*** initially 15 out of the 30 farms had a AD installation; however it had broken down seriously on 2 of them*

****most of these pits are emptied passively once filled via a gutter, leading excess liquids to streams or rivers; the solid sediment is removed and may be used as fertilizer*

Around 30% of farms release the slurry directly into the environment. Many of these farms happen to be relatively large (on average 509 pigs per farm). Consequently a much larger share of total amount of slurry produced (55%) is directly disposed of into the environment. In terms of N and P, however, these wasted slurries represent circa 38% of the excreted N and 6% of the excreted P (Figure 2). Collection for further handling is, however, not a guarantee for utilization as a fertilizer, as shown in Figure 2. All in all, the estimated utilization as fertilizer amounts to less than 50% for the excreted N (assuming nil gaseous N losses for the sake of simplicity) and around 90% for P. If the population included in the survey is considered representative for Gia Kiem as a whole, these assumptions and outcomes would imply that the, on average, 22.3 pigs per hectare (55722 heads / 25 km^2) would emit at least 120 kg N (22.3 x 10 x (1-0.46)) per hectare to the air and water and at least 7 kg P_2O_5 (22.3 x 4 x (1-0.92) per hectare to water.

3.4 Constraints and advantages in manure management

As mentioned above, manure management is not only meant to reduce the environmental pollution from manure but also to use manure as a source of nutrients (N, P, K, C). Appropriate management of manure may be handicapped by technical constraints (collection, storage, treatment and transport), socio-economic constraints and institutional constraints.

To be able to use manure as fertilizer, livestock farms need collection, storage, processing, transport and appropriate equipment. The survey results showed (Table 8) that there are two major constraints discouraging the use of manure as a fertilizer. First, there is the lack of treatment capacity (93% of farms classify this constraint as important to crucial) and, secondly, there is lack of transport capacity (97% of farms classify this constraint as important to critical). Manure treatment includes composting, anaerobic digestion, separation into liquids and solids. The lack of treatment capacity felt by farmers pertains to the lack of infrastructure and capital for building biogas systems to treat the excreta. Most of the biogas systems were built with support from the government. However, many of these installations have been neglected and have by now collapsed due to lacking maintenance. In addition, the government does not yet have strict regulations on monitoring and fining farms whose pig excreta are directly disposed of into the environment. Collection capacity, storage capacity of farms and lack of suitable equipment to apply manures were not considered the main constraints undermining the use of manure as a fertilizer. This pointed out that the utilization of manure as valuable source of nutrients, is, at least in view of farmers, served by an improved processing of manure (converting manure into other forms of organic fertilizers by mixing them with agricultural by-products, composting them, packing them and make them ready for transporting to the market) and by extension of the transport capacity.

Table 8: Technical constraints discouraging the use of manure as a fertilizer

Criteria	Ratings (%)				
	Crucial	Very important	Important	Not so important	Irrelevant
Lack of collection capacity			17	63	20
Lack of storage capacity		7	17	53	23
Lack of treatment capacity	27	47	20	7	
Lack of transport capacity	13	40	43	3	
Lack of suitable equipment to apply manures		13	10	60	17

According to the interviewed farmers, socio-economic factors do not really appear to affect the farmers' decision to use manure as fertilizer. According to the survey (Table 9), transportation costs nor labor costs were considered a constraint to use manure instead of minerals fertilizers. According to 63% of the farmers high land costs neither affected the room for land spreading of manure. The use of manure as a fertilizer was also not undermined by the use of manure in aquaculture or its use as a fuel according to over 93% of the farmers.

Absence of information regarding measures to improve the management of manure, lack of access to the available information due to illiteracy, absence of interest in manure management, and lack of access to loans for the required investments in storage, treatment and transport were seen as (very) important to even crucial by 47%, 40%, 90%, and 73% of farms, respectively (Table 10). This means that there is a need to provide information on manure management, to enhance the farmer's awareness of manure management, and to invest in manure treatment systems.

Table 9: Socio-economic constraints discouraging the use of manure as a fertilizer

Criteria	Ratings (%)				
	Crucial	Very important	Important	Not so important	Irrelevant
Too high transport costs, relative to those needed for mineral fertilizers		3	23	63	10
Too high labor costs, relative to that needed for the handling of mineral fertilizers		7	17	67	10
Too high prices of land, providing room for land spreading:		17	20	53	10
Too low benefits when used as fertilizer, relative to benefits when used as a nutrient for aquaculture			7	17	77
Too low benefits when used as fertilizer, relative to benefits when used as a fuel			13	13	73

Table 10 : Institutional constraints discouraging the use of manure as a fertilizer

Criteria	Ratings (%)				
	Crucial	Very important	Important	Not so important	Irrelevant
Absence of information regarding manure management improvements		23	23	47	7
Lack of access to the available information due to illiteracy		20	20	53	7
Absence of interest in manure management	3	63	23		10
Lack of access to loans for the required investments in storage, treatment and transport	10	60	3	20	7
Lack of access to required equipment and machines for storage, treatment and transport	10	13	3	67	7
Lack of trading infrastructure			17	77	7
Lack of regulations creating a level playing field for all farmers			27	60	13
Spatial separation of livestock farms and arable farms due to specialization		17	57	17	10

As stated above, the production system is quite the same across farms, as it is focused mainly on raising pigs without clear links between the animal production part and the crop production component providing feed and spread lands for manure. This feature of the pig production system in the survey area was one of the major constraints for using of manure as fertilizer for crops. Twenty two out of the 30 farmers (73%) agreed that this is an important obstacle.

Improving manure management

Manure management is not just related to using manure as a source of fertilizer but also to limiting the negative impact of manure to the environment. Improvement of manure management is hence also needed to limit that negative impact. All farmers participating in the survey agreed that this is (very) important or even crucial, mainly because of its direct effect on human and livestock health, on water quality and on odor emissions. Other aspects such as the fertilizer replacement value of manure and the attending potential income from selling manure, were considered to be important by only 7 out of 30 farms (23%). It means that from the point of view of many farmers, manure is just a 'waste' and not yet a valuable by-product from livestock enterprises.

Table 11: Major reasons to improve manure management

Criteria	Ratings (%)				
	Crucial	Very important	Important	Not so important	Irrelevant
On-farm hygiene, considering human health	60	40			
On-farm hygiene, considering animal health	30	63	7		
Water quality, from the point of view of human and animal health	57	43			
Water quality, from the point of view of fishery quality	10	7		3	80
Abatement of odour problems, also for neighbours	43	53	3		
Missed fertilizer value for the crops grown by the farm itself		33	37	23	7
Missed income when sold as a fertilizer for other farms			23	77	

Up to 63% farms had so far not received any information on manure management methods in the past two years. For the remaining farms (37%), information came mainly from the local government (82%). Improvement of the manure management may hence benefit from the establishment of information channels to the farmers.

General observation

Considering their pleas for 'manure treatment', many farmers appear to think that the re-introduction of AD would be able to reduce emissions and improve the utilization of resources. Undoubtedly AD would capture and utilize C (i.e. CH_4) that would otherwise be lost to the detriment of the environment because CH_4 is a potent GHG. However, AD has no effect at all on the contents of total N and total P and does not alleviate the need to address the potential emissions of N and P. The partial conversion of organically bound N into ammoniacal N, makes is even more important to pay due attention to an adequate timing and incorporation of digestates once they are applied to land. If the production of CH_4 out of manures is yet considered relevant, it may require some re-thinking of how waste flows are treated, as most C is contained in the solid fraction and not in the thus far AD-treated liquid fraction. This means that much more CH_4 could be produced by including the solids in the AD. One could reason that solids can then no longer be easily collected and packed for transport to other destinations, once liquids and solids would both be AD-treated. If, however, such an AD would be followed by a separation step, the solid fraction coming out of that would not at all have lost any of its commercial value for farmers that are willing to pay for the current types of solid manure (Hjorth et al. 2010; Foged et al. 2011). In view of rising prices of fossil fuels (mainly relevant from the perspective of N fertilizer production) and declining reserves of fossil rock phosphate (relevant from the perspective of P fertilizer production) it is key to look for integral approaches that address C, N or P utilization simultaneously instead of separately.

4. Conclusions and recommendations

- The farms included in the survey had specialized in intensive pig farming. They had an average herd size of 279 heads per farm, of which 62% referred to fattening pigs. According to the 2012 book keepings every farm sold 540 fattening pigs at an age of 6 months and an average body weight of 100 kg. All farms use compound feeds and keep the animals within housing according to an industrial approach.

- The farms included in the survey all produced two types of waste: (i) solid manure (feces) and (ii) a mixture of feces, urine and flushing water (slurry). All farms used large amounts of water for cleaning, 35 liters (including drinking water) per fattening pig or sows per day.

- The slurry was stored on 67% of farms. Of this stored slurry 65% was used for anaerobic digestion. The digestate was used as a fertilizer for crops or directly discharged into the environment. The remaining 35% of the farms stored the slurry in ponds nearby.
- Solid waste was collected actively. On average, each farm collected 609 kg of fresh weight of solids per day. Eighty seven percent of these solids were transported actively by middle man and sold to plant growers elsewhere.

- In view of the farmers, lack of treatment capacity, lack of transport capacity, absence of information regarding measures to improve the management of manure, absence of interest in manure management, and lack of access to loans for building manure management system, were the important factors discouraging the use of manure as fertilizer.

- Socio-economic constraints did not really hinder the decision to use manure as fertilizer on the farms.

- The major consideration to improve manure management is that manure has a direct impact on the health of humans and animals, on water quality and on odor emissions to residential areas.-

- Treatment techniques addressing C-related, N-related or P-related issues separately should be avoided and instead be replaced by integral solutions encompassing C, N and P together.

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