Characterization of pig manure management and associated environmental and health issues in central Uganda

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Background

Pig production in Uganda is on the increase; between 2007 and 2017, the pig population in the country increased by 24%, and per capita pork consumption is the highest in East Africa at 3.4 kg per year (Roesel et al. 2017). The increase in pig production can be attributed to the increasing demand for pork as a result of population growth and urbanization, as well as a change in dietary preference (Thornton 2010).

Together with the increasing number of pigs, pig manure production is also increasing. If stored and handled well, livestock manure is a material rich in nutrients and organic carbon and can act as a soil conditioner that improves soil structure and water holding capacity and reduces erosion risks (Bronick et al. 2005). Pig manure can also be used to produce biogas in anaerobic digesters. Biogas can be used as cooking fuel reducing the need to collect firewood and reducing household air pollution (Lewis et al. 2017) while at the same time mitigating manure greenhouse gas (GHG) emissions and reducing pathogens in the environment (Avery et al. 2014). In Uganda, there are some reports of a few institutions and farmers using manure as a substrate to grow worms such as black soldier fly larvae (vermi-compositing), a manure management technique that has many positive aspects including (i) the larvae turn the manure into compost that can be used as fertilizer, (ii) during the vermi-composting process, the survival of pathogens is reduced (Lalander et al. 2015), which makes the compost safer for use, and (iii) the larvae can be used as a protein source by feeding them to fish, chicken and pigs (Oonincx et al. 2015).

However, if pig manure is not managed well, this has environmental and health implications. For instance, several studies have observed that pig manure can host pathogens such as *Salmonella, Campylobacter*, viruses such as African Swine fever (ASF), as well as parasites that can be transmitted to humans and other livestock (Bicudo et al. 2003; Guan et al. 2003; Guinat et al. 2016; Ström et al. 2018; Venglovsky et al. 2018). There is also a risk of emergence of antimicrobial resistance (AMR) in human and livestock pathogens because pig farming is often associated with misuse and overuse of antibiotics, and these and their residues are excreted with the manure and can lead to the spread of AMR into the environment (Kang et al. 2018; Xie et al. 2018). A recent study in central and western Uganda (KAKOOZA et al. 2021) revealed existence of Antimicrobial Genes (ARG) in manure from antibiotic treated animals even in areas with no history of antibiotic usage. Despite the associated health risks, the manure handling aspects to avert potential risks of transmission of zoonotic diseases from pig manure to farmers and exposure to AMR pathogens is not addressed in the 2016 Ugandan National Fertilizer Policy (MAAIF 2016).

In addition to animal and human health concerns, there are environmental concerns related to pig manure. For instance, manure and manure management contribute largely to GHG emissions from the livestock sector in Uganda (MWE 2019), but minimal field data on manure management practices exist. Since the livestock sector is a major contributor to national GHG emissions in Uganda, the Intergovernmental Panel on Climate Change (IPCC) recommends using a more accurate country-specific Tier 2 methodology to estimate GHG emissions from the individual emission sources, but so far, the data required to estimate GHG emissions from manure management is not widely available for Uganda. In addition to GHG emissions, manure from pig production systems produces a foul smell, which can create conflict between pig keepers and neighbouring residents in urban and peri-urban areas (Alvåsen 2009; Nantima et al. 2015). Furthermore, ammonia emissions from pig manure lead to acidification of rainwater (Burns et al. 2016; Kruse et al. 1987) and eutrophication of water bodies (Daniel et al. 1998).

Despite the many positive and negative aspects of pig manure, there are few *in situ* data about existing pig manure management practices in Uganda, which limits the uptake of climate-smart and safe manure management practices by pig famers (Wanyama et al. 2019).

To close this knowledge gap, we conducted a survey of smallholder pig manure management systems in central Uganda. More specifically, the present study aimed at

- characterizing pig production systems in Central Uganda and identifying key issues with pig manure management to identify opportunities for its improvement; and
- generating data for the estimation of baseline GHG emissions from pig manure following the IPCC Guidelines for National GHG Inventories (IPCC 2006).

The overall goal of this study was to contribute to sustainable pig production by highlighting options to reduce environmental pollution and health and safety concerns, and to transform the perception of manure from being seen as waste to a resource that can help to improve food security as a fertilizer, animal feed and source of clean energy.

Material and methods

This study was carried out in central Uganda in the districts Masaka, Mukono, Mpigi and Wakiso. The International Livestock Research Institute (ILRI) promotes sustainable pig production in Mukono and Masaka, and farmers in the two districts have been sensitized on sustainable pig production through radio messages. On the other hand, Mpigi and Wakiso are control districts without interventions.

Household interviews of farmers in rural, peri-urban and urban centres were conducted to capture the variability in pig production systems and associated manure management systems in the area. Here, rural areas are defined as sites away from towns/cities, with large farming lands and the region being generally sparsely populated. Peri-urban areas are those on the periphery of towns/cities with smaller farming lands, while urban areas are located within towns/cities. In addition to collecting information on pig manure management practices, we aimed to identify farmer perceptions regarding environmental and health concerns as well as barriers to improved pig manure management practices. To select the households for the interview, we used the database from a previous baseline Rural Household Multi-Indicator Survey (RHOMIS survey), which was conducted on 648 households in the study area. We randomly selected and interviewed a subset of 288 households from the RHoMIS database of 648 households. Results from this survey were summarized and described using descriptive statistics. Responses for the variables on 'opinion on improved manure management' and 'drivers of manure management' were on a scale from 1 through to 4 with 1 being most important and 4 not important. To determine the magnitude of the variables, weights were calculated considering the number of respondents for each rank. Rank 1 was assigned value of 0.75, rank 2 0.5, rank 3 0.25 and rank 4 was assigned 0 (Tofallis 2014) . The assigned ranks were correspondingly multiplied by the corresponding number of respondents for each variable. For each criterion we added together all the values, and divided each one of them by this total for each cluster. This allowed scores to be viewed as proportions of some whole, and proportionality of scores was retained. The magnitude of importance of the variable therefore depended on the rank and the proportion of respondents under each cluster and site.

Results

Farm characterization

All interviewed farmers in this study are categorically pig farmers clustered under urban, peri-urban and rural areas. Besides keeping pigs, the farmers also keep cattle, chicken and goats (Table 1). Other livestock species (e.g. turkey, rabbits, sheep) are of minor significance.

Table 1: Characterization of livestock kept by pig farmers in Masaka, Mukono, Mpigi and Wakiso

District	Area	Households	Pigs Range	Mean ± SE	%		Mean ± SE	%	Cattle Range	Mean ± SE	%	Chicken Range	Mean ± SE	%
Masaka	Peri-urban	36	1-65	9.2 ± 1.9	100	1-3	2.3 ± 0.2	11	2-886	197 ± 47	36	1-10	5 ± 0.6	11
	Rural	20	1-70	13.6 ± 3.7	100	1-6	2.7 ± 0.2	35	2-450	63 ± 26	100	1-8	3 ± 0.5	55
	Urban	25	1-20	6.9 ± 1.0	100	1-5	2.5 ± 0.2	16	1-270	80 ± 21	52	1-6	3 ± 0.4	24
Mukono	Peri-urban	50	1-19	4.8 ± 0.6	100	1-7	2.8 ± 0.2	12	1-200	23 ± 8	26	2-5	3 ± 0.3	10
	Rural	30	1-45	7.8 ± 1.9	100	1-10	2.9 ± 0.2	70	2-50	13 ± 2.4	77	1-12	3 ± 0.5	57
	Urban	15	2-25	7.3 ± 1.7	100	1-5	3 ± 0.2	13	6-40	18 ± 2.0	40	1-5	3 ± 0.3	40
Mpigi	Peri-urban	20	1-15	3.95 ± 0.9	100	1-6	3 ± 0.4	45	2-55	14 ± 4	71	1-8	4 ± 0.4	60
	Rural	45	1-31	7 ± 1	100	1-7	2 ± 0.2	53	2-460	33 ± 13	67	1-16	4 ± 0.4	40
	Urban	3	1-26	11 ± 8	100	1-1	0		2-100	51 ± 39		0	0	0
Wakiso	Peri-urban	6	20-514	131 ± 78	100	1-8	5 ± 2	33	5-100	67 ± 42	17	8-20	14 ± 2.5	50
	Rural	6	3-79	21 ± 11	100	1-4	4±0.5	17	0-3	6 ± 2	50	1-4	3 ± 0.8	33
	Urban	32	1-53	11 ± 2	100	1-7	5 ± 0.5	9	0-5	127 ± 32	34	0-3	3 ± 0	6
Average					100			29			52		32	

SE, standard error of the mean; %, percentage of farmers keeping the respective livestock

Overall, we found that pig farmers keep between 1 and 514 pigs, with the mean ranging from 5 to 14 pigs across districts and systems (Table 1). Households where mostly smallholder pig farms: 44% of farmers owned between 1-4 pigs, 31% owned between 5-10 pigs, 15% owned between 11-20 pigs, and only 9% of farmers owned between 21-65 pigs. Pig farmers also keep other livestock such as cattle (29%), goats (32%) and chicken (52%). These other livestock are mostly found in the rural households followed by the peri-urban households (Table 1).

In addition to livestock farming, crop production is a major component of the farming system in this region. The major crops are cooking bananas (matoke), coffee, maize and beans.

Figure 1: Housed pigs.

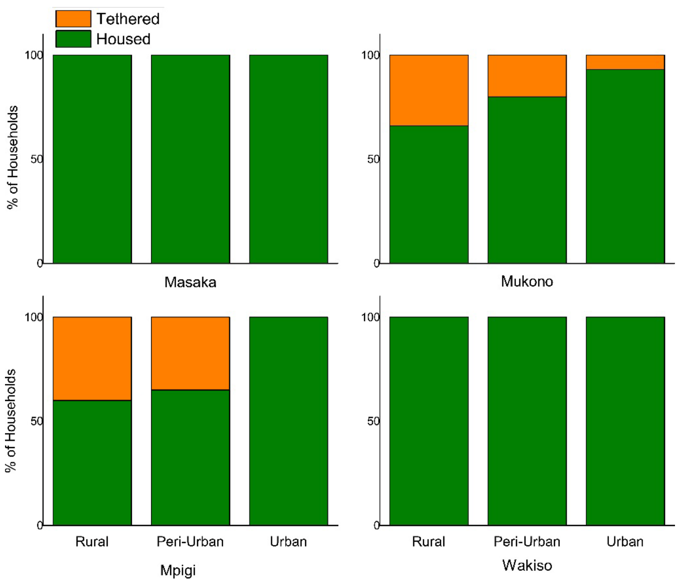
Figure 2: A tethered pig.

Photo credit: Ibrahim Wanyama/ILRI.

Pig housing

Pigs were mostly kept under confinement across the three clusters, either in pig houses (89%, Figure 1) or by tethering (11%, Figure 2), throughout most of the year (Figure 3). Tethering is mostly practiced in rural areas, especially among low-income farmers who are unable to construct pigsties because of income constrains. In addition, in a few farms in the rural areas (5%), we found that piglets <2 months old were left to roam around within the farm (free range). In all cases, the reason for confinement is to prevent conflicts as a result of pigs eating the crops of neighbours, as well as for religious reasons, particularly the Muslim community is offended when they come in contact with roaming pigs, pigs are a taboo to the Muslims.

Figure 3: Pig confinement methods in the study sites.



Pig houses are usually partitioned, with each partition housing between 1-10 pigs depending on the age. Sows and boars are usually housed individually in separate partitions, while 2-3 growing pigs can be housed together in a partition. Weaners of the same age are housed together, with a partition holding up to 12 weaners.

We characterized pig housing based on the roofing, floor, and fence, by dividing them into three categories:

i. Floor-Roof-Fence (FRF) where the house is enclosed and has a concrete floor and a roof (Figure 4).

ii. Fence-Roof (FR) where the house is enclosed and has a roof. Typically, the floor is a raised slated wooden floor or non-concrete floor where urine and dung mix.

iii. Fence-Floor (FF) where the house has no roof but is enclosed and has a concrete floor (Figure 5).

Across the study, the FRF system was the most prevalent type of housing among the farmers with pig houses (69%), followed by FR (28%), while only 3% of farmers had an FF confinement system (Table 2).

Figure 4: A pig house with floor, roof, and fence (FRF system).

Photo credit: Ibrahim Wanyama/ILRI.

Figure 5: A pig house with no roof (fence-floor system, FF).

Table 2: Characteristics of pig houses in Masaka, Mukono, Mpigi and Wakiso

District	Cluster	Households	Pig house characteristics (%)		
			Floor-Fence-Roof	Fence-Roof	Fence-Floor
Masaka	Rural	36	80	17	3
	Peri-urban	20	85	15	0
	Urban	25	65	31	4
Mukono	Rural	50	72	25	3
	Peri-urban	30	82	18	0
	Urban	15	88	6	6
Mpigi	Rural	20	89	7	4
	Peri-urban	45	77	23	0
	Urban	3	100	0	0
Wakiso	Rural	6	100	0	0
	Peri-urban	6	100	0	0
	Urban	32	69	28	3

Labour

Pig production involves a number of routine management practices such as feeding, cleaning of the pig houses, and manure management. Labour is majorly provided in-house by family members on most of the farms. In most of the households labour is provided by the head (38% of households), followed by the children (23%), and the spouse (15%) and these often work together. Hired labour was observed in only 17% of the households (Figure 6 and Table 3).

Figure 6: Family labour predominates in pig production systems in central Uganda.

Photo credit: Ibrahim Wanyama/ILRI.

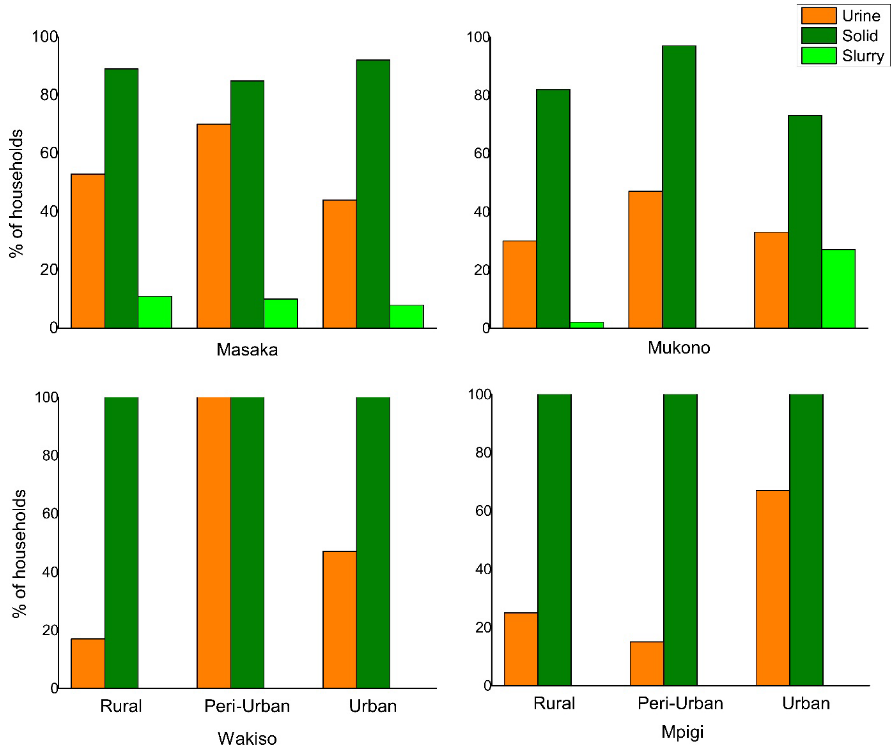
Table 3: Labour for pig production and manure management in Masaka, Mukono, Mpigi and Wakiso

District	Cluster	Households	Head (%)	Spouse (%)	Children (%)	Other relative (%)	Hired labour (%)
Masaka	Rural		27	20	27	10	17
	Peri-urban	36	44	13	28	3	13
	Urban	20	37	21	27	2	13
Mukono	Rural	25	25	13	41	13	9
	Peri-urban	50	70	15	15	0	0
	Urban	30	26	25	26	20	3
Mpigi	Rural	15	49	17	20	12	5
	Peri-urban	20	32	21	25	18	4
	Urban	45	67	0	0	0	33
Wakiso	Rural	3	29	14	14	0	43
	Peri-urban	6	13	25	13	0	50
	Urban	6	37	0	43	6	14
Average			38	15	23	7	17

Manure management

The manure components of urine and dung are handled either mixed or separately in three different ways depending on the liquidity: as separated urine, as solid manure (mix of dung and other organic wastes, sometimes together with urine), and as slurry (a mixture of dung, urine and flush water from cleaning the pens) (Figure 7).

Figure 7: Pig manure handling under the different clusters (rural, urban and peri-urban) in the study areas.



NB: 'Slurry' is the mixture of dung and urine with flush water, 'solid' is solid dung often mixed with other organic waste, and 'urine' describes the active separation of urine from dung and its collection. Households that separate urine usually also collect solid manure.

a. Urine storage

Overall, approximately 46% of farmers keep and handle urine separately from the other components (Figure 7) in the four (4) districts. The major reason for separating urine from the dung is to reduce on the odor from the manure. Among those farmers who separate urine, 55% of them keep the urine in pits, while the other 45% discharge the urine into the surroundings (Table 4).

Table 4: Fate of pig urine in the study area

District	Cluster	Urine utilization			
		Households	Fertilization (%)	Given out/ sold (%)	Discharged (%)
Masaka	Rural	36	37	11	53
	Peri-urban	20	36	0	57
	Urban	25	36	0	64
Mukono	Rural	50	40	0	67
	Peri-urban	30	43	0	57
	Urban	15	60	0	20
Mpigi	Rural	45	36	0	64
	Peri-urban	20	100	0	0
	Urban	3	0	0	100
Wakiso	Rural	6	100	0	0
	Peri-urban	6	67	0	33
	Urban	32	13	7	80
Average			47	1	50

For the farmers who have urine pits, 44% of the pits had concrete floors, 22% had a roof, and only 4% had a cover, herein cover refers to use of any materials such as crop residues, cloth, placed directly on the manure.

Approximately 47% (Table 4) of the farmers who collected urine used it for fertilization of crops, and some farmers acknowledged that on top of urine being a fertilizer, it also controls banana weevils (*Cosmopolites sordidus*), which is one of the most serious insect pests in banana production. Despite the usefulness of urine as a fertilizer and for bio-control of weevils, some farmers (50%) discharged urine into the surrounding areas because of a lack of knowledge of the benefits of urine in crop production. Other reasons for this were lack of labour to apply urine, lack of buyers for the urine, and farms being too far from the pig houses.

Figure 8: Pig urine (left, in the pit) and solid components of manure (right, on the heap) stored separately.

Photo credit: Ibrahim Wanyama/ILRI.

A great amount of urine is also lost through leaching in pits that have no concrete floors (Figure 9). There are, however, some farmers (only 4 of the interviewed farmers) who use 20-litre jerricans and place them in the pits to collect urine and minimize the leaching losses (Figure 10).

Figure 9: Urine storage in a pit with no floor and cover: a lot of the urine nitrogen is lost through leaching and volatilization of ammonia.

Photo credit: Ibrahim Wanyama/ILRI.

Figure 10: A rudimentary way of urine collection that can be used in place of a concrete floor pit.

Photo credit: Ibrahim Wanyama/ILRI.

b. Solid manure management

The majority (93%) of farmers handled manure in solid form. Solid manure in the study area is either a mixture of dung, urine and organic wastes (in 61% of households), or a mix of dung and organic wastes (39% of farmers) (Table 5). The organic wastes are mainly either crop wastes or forages (mainly weeds used as feeds) that are feed leftovers.

Table 5: Composition of pig manure and solid manure storage methods

			Components of solid wastes		Solid manure storage methods				
District	Cluster	Households	Dung + organic wastes (%)	Dung + Urine + organic wastes (%)	Drying (%)	Heaping (%)	Pit storage (%)	Daily spread (%)	Deep bedding (%)
Masaka	Rural	36	71	29	0	72	22	6	0
	Peri-urban	20	80	20	6	41	47	6	0
	Urban	25	65	35	4	78	9	9	0
Mukono	Rural	50	21	79	18	55	8	20	0
	Peri-urban	30	33	67	19	50	8	19	4
	Urban	15	55	45	10	60	20	10	0
Mpigi	Rural	45	5	95	40	48	5	2	5
	Peri-urban	20	6	94	29	47	6	18	0
	Urban	3	0	100	0	67	0	0	33
Wakiso	Rural	6	0	100	33	33	17	17	0
	Peri-urban	6	83	17	17	33	17	33	0
	Urban	32	45	55	21	46	11	11	11
Average			39	61	17	53	14	13	4

We observed four major solid storage methods: the most important method was heaping (53% of households), followed by drying (17%), pit storage (14%), daily spreading (13%), and deep bedding (10%) (Table 5). We also found out that the majority (81%) of the manure storage facilities neither had a roof nor a floor.

Most of the farmers (78%) use solid pig manure for fertilization of crops, while 16% of the farmers give away or sell part or all the solid manure (Table 6). Only 2% of the farmers do not use manure at all but rather dispose of it. This was mainly observed in urban areas. The reasons given for not using pig manure ranged from lack of knowledge, lack of farms to apply the manure, farms being too distant, and lack of labour.

Table 6: Characteristics of solid manure storage facility and solid manure utilization

Solid manure storage facility					Solid manure utilization			
District	Cluster	Households	Cover/roof (%)	No cover/ roof (%)	Fertilization (%)	Sold/given (%)	Discharged (%)	Manure Left to decompose (%)
Masaka	Rural	36	3	97	81	14	0	0
	Peri-urban	20	12	88	75	25	5	0
	Urban	25	22	78	68	36	4	0
Mukono	Rural	50	0	100	70	6	0	12
	Peri-urban	30	3	97	87	7	3	3
	Urban	15	0	100	67	0	0	7
Mpigi	Rural	45	14	86	93	0	2	0
	Peri-urban	20	0	100	85	10	0	0
	Urban	3	0	100	67	33	0	0
Wakiso	Rural	6	0	100	83	0	0	17
	Peri-urban	6	0	100	100	33	0	17
	Urban	32	7	93	66	25	9	28
Average			5	95	78	16	2	7

c. Slurry storage

Slurry storage was the least used method of manure storage, being practiced by only 13% of the interviewed farmers. The slurry was mostly stored in pits (70%), while in other farms it was left to freely flow on the soil surface surrounding the farms (23%). Similar to solid manure storage, slurry storage facilities had neither floor nor cover. We only observed slurry storage in Mukono and Masaka, where sustainable pig farming methods are advertised through radio programs, but not in Mpigi and Wakiso.

Hygiene

Most farmers cleaned the pig houses on daily (mean across the districts was 73%) (Table 7). There was a gradient across systems, with a lower percentage of households cleaning the pig houses every day in rural areas (40%) and in peri-urban areas (60%) in Mukono District, and in rural (44%) and peri-urban areas in Mpigi district (35%) (Table 7).

Weekly cleaning was the second-most practiced (16%) routine, and this was observed mainly in control districts of peri-urban Mpigi (30%) and rural Wakiso (33%) (Table 7).

There were also farms where no cleaning was done, and these were all using the tethering system where animals are tethered to a tree and are moved periodically from one spot to another once too much manure accumulates. In these cases, manure is not collected.

Table 7: Pig house cleaning frequency (manure removal)

District	Households	Cluster	Pig house cleaning frequency (%)				
			Daily	Weekly	Weekly	More than half a year	Never
Masaka	36	Rural	85	15	0	0	0
	20	Peri-urban	85	15	0	0	0
	25	Urban	92	8	0	0	0
Mukono	50	Rural	43	27	6	6	18
	30	Peri-urban	64	14	7	0	14
	15	Urban	76	24	0	0	0
Mpigi	45	Rural	56	25	7	1	11
	20	Peri-urban	35	30	10	0	25
	3	Urban	100	0	0	0	0
Wakiso	6	Rural	67	33	0	0	0
	6	Peri-urban	100	0	0	0	0
	32	Urban	81	6	6	3	3
Average			74	16	3	1	6

Disinfection of pig houses was practiced by only 23% of the farmers in in the study sites. Disinfection was practiced by fewer farmers (18%) at Mpigi and Wakiso districts compared to the Masaka and Mukono sites (30%) (Table 8).

The most commonly used disinfectants are JIK® (sodium hypochlorite), iodine, and Virkon® (potassium peroxymonosulfate). Other disinfectants used include wood ash and Indigenous Microorganisms (IMO). Some farmers washed their pig houses using water and detergents or soap.

Table 8: Pig house disinfection frequency and disinfectant types

District	Cluster	Households	Disinfection frequency (%)				Type of disinfectant (%)				
			Weekly	Monthly	Seasonally	Never	IMO	Iodine	JIK	Ash	Virkon
Masaka	Rural	36	14	8	3	69	3	3	11	3	6
	Peri-urban	20	35	15	0	50	0	15	15	5	10
	Urban	25	16	16	0	68	0	16	16	0	4
Mukono	Rural	50	4	2	0	88	0	0	4	0	0
	Peri-urban	30	10	10	3	67	7	0	13	0	0
	Urban	15	7	7	0	87	0	0	7	0	7
Mpigi	Rural	45	4	0	2	93	2	0	2	0	0
	Peri-urban	20	0	5	0	95	0	0	0	0	0
	Urban	3	33	0	0	67	0	0	33	0	0
Wakiso	Rural	6	0	0	0	100	0	0	0	0	0
	Peri-urban	6	0	17	0	67	0	0	17	0	0
	Urban	32	16	6	3	69	9	0	19	0	6
Average			12	7	1	77	2	3	11	1	3

The most widely used tool for dung collection from the pig houses was the spade (87% of farms) and hoe (5%), but some households do not collect pig manure (Table 9). It was observed that in many cases, farmers used very short brooms to aid with the collection of manure onto the spade or hoes, and during this process manure is splashed and gets in contact with the farmer's clothing or body, which may pose a health risk. About 62% of farmers used gumboots when handling manure, while gloves (8%) were the least used items.

Table 9: Tools used in manure handling for pig manure safety

District	Cluster	Households Gumboots	Manure handling tools (% of households)			
			Spade	Hoe	Gloves	
Masaka	Rural	36	53	81	6	3
	Peri-urban	20	35	100	0	0
	Urban	25	40	80	0	8
Mukono	Rural	50	58	68	10	10
	Peri-urban	30	73	70	13	10
	Urban	15	53	93	0	13
Mpigi	Rural	45	51	78	18	0
	Peri-urban	20	40	80	10	0
	Urban	3	100	100	0	33
Wakiso	Rural	6	83	100	0	17
	Peri-urban	6	83	100	0	0
	Urban	32	75	94	3	6
Average			62	87	5	8

The water sources for pig production and cleaning of the pens varied across seasons and sites. In the dry season, boreholes(56%) are the major source of water in Mukono, while piped water (68%) is the major source of water in Masaka. These sources are followed by rainwater (5%) and water from rivers (8%) (Table 10). In Mpigi and Wakiso, piped and borehole water are commonly used in the dry season. During the rainy season, more farmers resort to rainwater in Mukono (26%), Masaka (30%), Mpigi (35%), and Wakiso (59%). Accordingly, we observed a reduction in the use of borehole water for all the districts during the rainy season compared to the dry season (Table 10).

Table 10: Source of water for livestock during dry and rainy seasons

District	Cluster	Households	Source of water for livestock – Dry season (%)					Source of water for livestock use – Rainy season (%)				
			Borehole	Pipe	Rain	River	Other	Borehole	Pipe	Rain	River	Other
Masaka	Rural	36	9	44	21	21	6	8	31	39	11	11
	Peri-urban	20	0	85	5	5	5	0	60	30	5	5
	Urban	25	4	88	8	0	0	0	84	16	0	0
Mukono	Rural	50	66	10	4	12	8	56	6	24	8	6
	Peri-urban	30	61	29	4	4	4	50	29	18	4	0
	Urban	15	19	63	13	6	0	18	24	47	12	0
Mpigi	Rural	45	53	27	4	11	4	36	20	31	9	4
	Peri-urban	20	65	15	0	20	0	35	15	40	10	0
	Urban	3	0	33	33	33	0	0	33	33	33	0
Wakiso	Rural	6	33	17	17	17	17	17	17	33	17	17
	Peri-urban	6	0	17	0	17	67	0	0	83	0	17
	Urban	32	10	39	13	35	3	0	16	59	25	0
Average			27	39	10	15	9	18	28	38	11	5

Similarly, the source of water for domestic use varied across seasons and sites. During the dry season, the major water sources are piped water in Masaka (77%) and borehole water (55%) in Mukono. The other water sources are rainwater (3%) and river water (4%) (Table 11). In Mpigi, the major sources of water are borehole (36%) and borehole (28%) while river (28%) and piped water (28%) are commonly used in Wakiso during the dry season. During the rainy season, the use of borehole water in Mukono and piped water in Masaka while use of rainwater increased to 32 and 49%, respectively. A majority (77%) of farmers treated domestic drinking water by boiling before use to avoid water-borne diseases especially Typhoid fever.

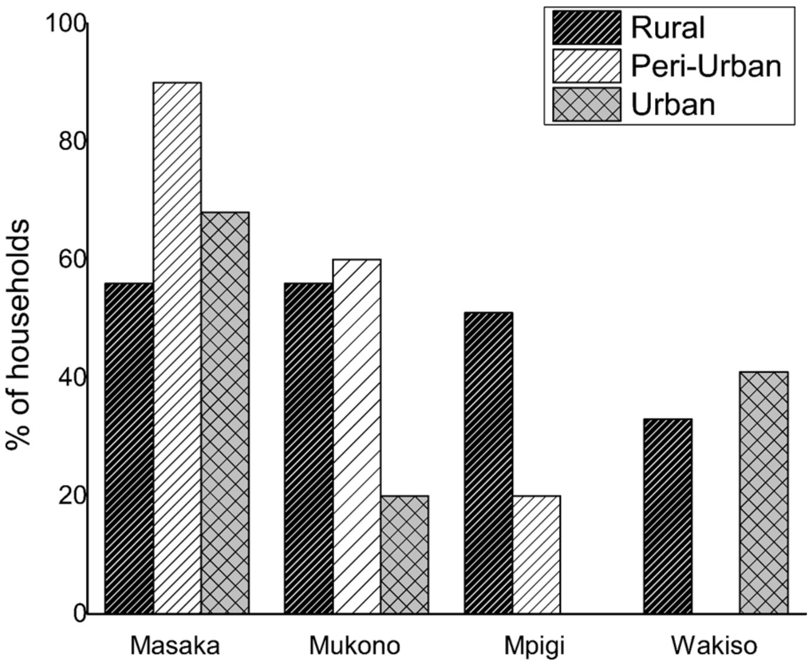
Table 11: Source of water for domestic use during the dry and rainy seasons

District	Cluster	Households	Source of water for household use-Dry season					Source of water for household use-Rainy season				
			Borehole	Pipe	Rain	River	Other	Borehole	Pipe	Rain	River	Other
Masaka	Rural	36	9	51	11	23	6	9	46	26	11	9
	Peri-urban	20	0	90	0	5	5	0	75	15	5	5
	Urban	25	4	92	0	4	0	0	92	8	0	0
Mukono	Rural	50	76	12	4	6	2	66	10	22	0	2
	Peri-urban	30	62	28	3	3	3	46	29	21	4	0
	Urban	15	27	73	0	0	0	20	53	20	7	0
Mpigi	Rural	45	50	24	15	0	11	0	32	43	14	11
	Peri-urban	20	58	13	4	8	17	59	10	28	3	0
	Urban	3	0	33	33	33	0	25	25	25	25	0
Wakiso	Rural	6	25	0	25	50	0	0	0	20	40	40
	Peri-urban	6	0	25	0	25	50	14	0	71	0	14
	Urban	32	9	59	12	9	12	0	34	56	6	3
Average			27	42	9	14	9	20	34	30	10	7

Perceived health hazards of pig manure

On average, 59% of pig farmers acknowledged that pig manure can be hazardous to humans, pigs, other livestock and the environment. The lowest cases of awareness of the hazards of pig manure were found in urban areas in Mukono (20%) and the highest in peri-urban areas in Masaka (90%) (Figure 11). Among the farmers who acknowledged that pig manure can be dangerous, 85% of the mentioned the risk of causing disease to humans, 52% mentioned transmission of disease to pigs, 44% mentioned air pollution, but only 6% mentioned transmission of disease to other livestock (6%), which was surprising given that a substantial number of farmers kept other livestock (Table 12).

Figure 11: Perception on health and environmental risks associated with pig manure by pig farmers.



NB: Percentages are calculated separately for each district and cluster. For instance, in Masaka 56% of rural farmers, 90% of peri-urban farmers, and 68% of urban farmers are aware of health and environmental risks associated with pig manure.

Table 12: Perception on health and environmental risks associated with pig manure by pig farmers

District	Cluster	Households	Can transmit human disease (%)	Can transmit pig disease (%)	Can transmit disease to other livestock (%)	Risk for water pollution (%)	Risk for air pollution (bad odour) (%)
Masaka	Rural	36	65	85	0	0	50
	Peri-urban	20	83	89	6	0	83
	Urban	25	94	82	18	0	65
Mukono	Rural	50	93	7	0	0	7
	Peri-urban	30	94	22	6	0	33
	Urban	15	33	33	33	0	67
Mpigi	Rural	45	96	9	0	0	35
	Peri-urban	20	75	0	0	0	50
	Urban	3	0	0	0	0	0
Wakiso	Rural	6	100	0	0	0	0
	Peri-urban	6	0	0	0	0	0
	Urban	32	69	23	0	0	46
Average			67	29	5	0	36

Majority of farmers (56%) of farmers reported pig disease(s)/symptoms/parasites occurrence that can be transmitted through pig manure. Worms were mentioned by 31% of the farmers, the other animal health issues mentioned were mange and ASF. The symptoms of pig disease mentioned in their order of importance were diarrhea (34%), coughing (22%), loss of appetite (12%), vomiting (9%), itching of the anus (6%), and weight loss (6%) (Table 13).

Table 13: Pig disease/parasite symptoms experienced at the pig farms

District	Cluster	Households	Coughing (%)	Diarrhea (%)	Vomiting (%)	Itching of anus (%)	Weight loss (%)	Loss of appetite (%)	Worms (%)	Other diseases
Masaka	Rural	20	5	60	10	10	10	10	30	10
	Peri-urban	18	0	33	0	0	6	11	17	22
	Urban	17	6	24	6	0	6	6	65	47
Mukono	Rural	28	25	7	7	7	4	14	21	4
	Peri-urban	18	44	39	11	11	0	11	22	17
	Urban	3	167	100	67	0	33	33	33	33
Mpigi	Rural	23	57	43	13	9	4	4	35	9
	Peri-urban	4	75	50	0	0	25	50	30	50
	Urban	0	0	0	0	0	0	0	0	0
Wakiso	Rural	2	50	0	0	0	0	0	30	0
	Peri-urban	0	0	0	0	0	0	0	0	0
	Urban	13	69	23	8	23	0	0	15	0

NB: 'Other diseases' includes mange and swine fever

Most farmers routinely treated their pigs against existing diseases or to prevent diseases. The most commonly administered treatment was against worms (86%), followed by mange (40%), diarrhea (14%), and coughing (6%) (Table 14). Treatment was mostly done based on recommendations of a local veterinary practitioner (100%), but at times some farmers treated their animals themselves (7%).

Table 14: Treated pig disease/parasite symptoms at the pig farms

District	Cluster	Households	Coughing (%)	Diarrhoea (%)	Vomiting (%)	Itching (%)	Weight loss (%)	Loss of appetite (%)	Worms (%)	Other diseases (%)
Masaka	Rural	36	0	25	0	0	3	3	83	33
	Peri-urban	20	0	15	0	0	5	5	90	25
	Urban	25	8	12	4	0	0	0	96	40
Mukono	Rural	50	8	2	4	4	0	2	90	50
	Peri-urban	30	17	17	7	0	0	7	77	43
	Urban	15	7	20	7	0	7	7	87	33
Mpigi	Rural	45	16	13	0	0	0	0	89	84
	Peri-urban	20	0	5	0	0	5	0	95	80
	Urban	3	0	0	0	0	0	0	0	0
Wakiso	Rural	6	0	0	33	0	0	0	83	67
	Peri-urban	6	0	0	0	0	0	0	0	0
	Urban	32	6	6	0	0	0	0	97	59
Average			5	10	5	0	2	2	74	43

However, upon checking, local veterinary practitioners negated this and reported that most farmers do not pay for the full dose up front and then rarely follow up to complete the remaining doses. The veterinary doctors also revealed that the major drugs they administer are dewormers, antibiotics, multi-vitamins, and acaricides.

Feeding

We observed two categories of feeding patterns of pigs:

a. without change in feeds between seasons (56%), and

b. with changes in feeding practices (type of feed and/or proportions of feeds) between season (44%).

Among those who did not change feeds across seasons (Table 15), crop residues (sweet potato vines, yam leaves, cassava, potatoes) were fed by 83% of the farmers, followed by home mixed feeds (60%), weeds (blackjack and Wandering Jew) (53%), commercial feeds (maize bran and assortment of ingredients) (38%). Restaurant remains (16%), other feeds (15%), kitchen refuse (10%), and brewery wastes (1%) are used by a few farmers (Table 15). In terms of quantities consumed, crop residues rank as the most consumed feeds, followed by commercial feeds, weeds and other feeds.

Table 15: Feed basket for pigs on pig farms where feeding does not change across seasons

District	Cluster	Households	No seasonal change (%)	Feed basket (%)								
				Commercial feeds	Kitchen refuse	Crop residues	Brewery wastes	Weeds	Home mixed	Restaurant refuse	Other feeds
Masaka	Rural	36	47	18	0	94	0	53	76	6	6
	Peri-urban	20	55	18	9	82	0	36	82	9	9
	Urban	25	44	36	64	73	0	82	55	18	0
Mukono	Rural	50	74	11	3	95	8	54	54	3	38
	Peri-urban	30	47	7	14	93	7	14	64	7	14
	Urban	15	67	10	20	90	0	30	80	30	10
Mpigi	Rural	45	27	42	0	92	0	92	83	0	17
	Peri-urban	20	50	40	0	90	0	70	60	0	20
	Urban	3	100	100	0	100	0	67	33	67	33
Wakiso	Rural	6	50	67	0	100	0	100	33	0	0
	Peri-urban	6	50	33	0	33	0	33	67	33	33
	Urban	32	56	78	6	50	0	6	28	22	0
Average			56	38	10	83	1	53	60	16	15

No seasonal change (%) is the percentage of farmers who feed pigs the same across dry and rainy seasons

For farmers who feed pigs differently during the dry and rainy season (56%), we observed differences in the type of feed and proportions of feeds between the two seasons (Tables 16 and 17). During the dry season, crop residues are predominantly fed to pigs (74%), 52% of the farmers used home mixed feeds, 50% used commercial feeds, 28% used weeds, while very few farmers (each below 5%) used kitchen refuse, brewery wastes, restaurant refuse and other feeds (Table 16). In terms of quantities, crop residues are the most consumed feeds, followed by home mixed feeds, commercial feeds. The other feeds are fed by a few pig farmers and in low quantities.

Table 16: Dry season feed basket for pig farms where feeding changes across seasons

District	Cluster	Households	Feed basket (%)									
			Seasonal change (%)	Commercial feeds	Kitchen refuse	Crop residues	Brewery wastes	Weeds	Home mixed	Restaurant refuse	Other feeds
Masaka	Rural	36	53	21	11	84	0	11	79	5	5
	Peri-urban	20	45	22	0	89	0	11	78	0	0
	Urban	25	56	21	7	71	0	21	79	7	7
Mukono	Rural	50	28	14	0	100	0	7	79	0	14
	Peri-urban	30	50	33	13	100	7	7	73	0	7
	Urban	15	33	80	0	100	0	0	20	0	0
Mpigi	Rural	45	73	73	0	94	0	76	70	0	6
	Peri-urban	20	50	80	10	70	0	60	70	0	0
	Urban	3	0	0	0	0	0	0	0	0	0
Wakiso	Rural	6	50	67	0	67	0	67	33	0	0
	Peri-urban	6	50	100	0	33	33	33	33	0	0
	Urban	32	44	86	7	79	0	43	7	29	0
Average			44	50	4	74	3	28	52	3	3

Seasonal change (%) is the percentage of farmers who feed pigs differently across dry and rainy seasons

During the rainy season (Table 17), more farmers used weeds (89%) as compared to the dry period, and this was followed by crop residues (82%). Commercial feeds (48%) and home-mixed feeds (51%) feeds use did not change during the two seasons. Just like in the dry season, the use of restaurant remains (4%), kitchen wastes (2%), brewery wastes (2%) and other feeds (2%) was low. However, the quantity of commercial feeds and crops used in the rainy season was almost half of what was fed in the dry period, while the quantities of weeds increased by almost 80%. The quantities of crop residues and the rest of feeds were fed in very low quantities.

Table 17: Rainy season feed basket for pig farms where feeding changes across seasons

District	Cluster	Households	Seasonal change (%)	Feed basket (%)							
				Commercial feeds	Kitchen refuse	Crop residues	Brewery wastes	Weeds	Home mixed	Restaurant refuse	Other feeds
Masaka	Rural	36	53	26	5	89	5	89	74	5	0
	Peri-urban	20	45	22	0	100	0	89	78	0	0
	Urban	25	56	29	0	93	7	100	71	7	0
Mukono	Rural	50	28	14	0	100	0	93	79	0	21
	Peri-urban	30	50	27	7	100	7	100	73	7	0
	Urban	15	33	80	0	100	0	100	20	0	0
Mpigi	Rural	45	73	58	0	97	0	100	70	0	3
	Peri-urban	20	50	70	10	90	0	100	70	0	0
	Urban	3	0	0	0	0	0	0	0	0	0
Wakiso	Rural	6	50	67	0	67	0	100	33	0	0
	Peri-urban	6	50	100	0	67	0	100	33	0	0
	Urban	32	44	79	7	79	0	100	7	29	0
Average			44	48	2	82	2	89	51	4	2

Seasonal change (%) is the percentage of farmers who feed pigs differently between dry and rainy seasons

Opinions on manure management

We investigated the importance of various technical and socio-economic constraints on pig manure management. Our results show that the constraints can be grouped into three categories based on the magnitude of importance. The first category comprises the most important constraints and these included: lack of information on manure management, high labour costs, lack of storage capacity, lack of treatment capacity, and limited collection capacity.

Table 18: Order of importance of constraints to optimal manure management

Constraint to optimal manure management	Weighed magnitude of driver	Importance of the constraint	Cluster(s) where constraint is experienced
Manure treatment capacity	0.15	Very important	Rural, Peri-urban and Urban
Storage capacity	0.14		
Lack of information	0.14		
Labour cost	0.13		
Manure collection capacity	0.13		
Manure transport capacity	0.08	Important	Urban and peri-Urban
Lack of application equipment	0.08		
Fields too far from the pig farm	0.06		
No market for manure	0.04		
Land price high	0.04		
High labour cost compared to inorganic fertilizer	0.01	Slightly important	Urban, peri-urban and rural
Low benefits of manure compared to inorganic fertilizer	0.01		
Manure does not increase yield	0.01		
Costs of use of manure high compared to inorganic fertilizer	0.01		
No access to loans	0.00		

These factors did not differ substantially across the three clusters of rural, peri-urban and urban areas. The second category of constraints was approximately half in magnitude of importance compared to the first category and included: lack of transport, fields where to apply manure to are too far away, no market for manure, and land being very expensive (Table 18). These constraints were very important in the urban and peri-urban areas. The third category was related to advantages of using inorganic fertilizers over manure in regard to labour costs, crop yield responses, and cost of manure. These constraints had no or very low influence on manure management as only a few farmers used inorganic fertilizer. And even the few who used inorganic fertilizer still ranked the related constraints low.

Drivers of improved manure management practices

We assessed what drives farmers to improve their manure management. Results showed that the most important considerations for manure management were to improve animal and human health and to prevent bad smell from manure. Improving the quality of fertilizer was ranked number 2, and this factor is about 30% as important as the first set (Table 19).

The least important considerations in manure management was to prevent water contamination and to improve manure quality for sale value was approximately 37 times less important compared to the first set of considerations (human and animal health, and odour management) (Table 19). Government regulations and incentives played only a marginal role in manure management.

Table 19: Drivers for improving manure management

Drivers for improved manure management	Weighed magnitude of driver	Importance of the constraint	Cluster(s) where constraint is experienced
Improve human health	0.229		
Improve animal health	0.229	Very important	Urban, rural and peri-urban
Odor management	0.226		
Improving own fertilizer quality	0.162	Important	Rural
To avoid water pollution for humans	0.065		
To avoid water pollution for animals	0.062		
Improving quality for selling manure	0.024	Not so important	Urban, rural and peri-urban
Incentive by government	0.002		
Regulation	0.002		

Summary of key observations and implications

1. In peri-urban and urban areas, almost all pigs are confined in pig houses, while in rural areas some farmers (depending on their financial ability) keep their pigs in houses and others use tethering. Under the tethering method, piglets <2 months old usually are on free range but do not go far from their mothers.
2. Many farmers are not aware of the risk of transmission of pathogens from manure to farmers, other pigs, and livestock, and this is coupled with inadequate use of protective gear while managing manure. Although some farmers use gumboots, the use of other protective gear such as gloves and masks is almost completely absent. We also observed low use of disinfectants while cleaning pig houses, which increases the possibility of build-up of zoonotic pathogens such as *Salmonella*. Additionally, there is a high risk for the spread of AMR because antibiotics are used frequently, and doses are often not completed.
3. Although some pig farmers utilize manure to improve soil fertility, manure management is not optimally done to preserve nutrients. Among farmers who separate dung and urine, most are not aware of the value of urine. Most farmers store solid manure in heaps, but these are not turned to aerate for composting. This can lead to high GHG emissions and does not make use of the sterilizing power of heat generated in compost heaps. Additionally, the manure heaps are usually not protected from rainfall or sunlight, which may facilitate spread of pathogens by insects and leads to high nutrient losses through leaching. We also observed poor application practices of manure to soils, where the manure is not incorporated into the soil but applied on the surface (especially when applied in banana plantations), thereby exposing it to direct sunlight and rainfall.
4. Farmers are often not aware or not concerned about the potential risk of manure contaminating water bodies. Consequently, there is little effort to improve manure management practices to mitigate contamination of water and soil. In some cases, urine is discharged directly into fields and ends up downstream in rivers and lakes.
5. In peri-urban and urban areas, land sizes are often too small or cropland is too far away to accommodate the manure produced by pigs. Therefore, the demand for manure among urban and peri-urban dwellers is low, and as a consequence, the manure is left to decompose or is discharged as a waste.
6. We observed seasonal variations in feeding patterns, which is important information for establishing precise GHG inventories from the pig sub-category.

Conclusion

This study provides the first comprehensive dataset (Annexed) for pig manure management in central Uganda. The data show that pig manure use as fertilizer for crop production is widely practiced, but current manure management practices lead to high nutrient losses. In addition, many health and environmental concerns remain unaddressed. To improve fertilizer quality and reduce the health and environmental footprint of pig production, pig manure storage and application has to be improved and pig farmers should be educated about the health risks and environmental consequences of current practice as well as good manure management techniques.

Annex

Dataset: https://hdl.handle.net/10568/117268

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