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Crop residue utilization and manure management practices in Peri-Urban Dairy Production Systems in Kisumu County, Kenya

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Abstract The study established that the predominant crop residues were green maize stover (40.70%), dry maize Stover (16.80 %,), and green maize cob and kernel Stover (13.50%) in semi-zero grazing systems. In low percentages were vegetable waste, banana residue, and sweet potato vines. These residues are primarily utilized as livestock feed (55.9%), organic fertilizer (19.7%), mulch (14.4%), livestock housing and bedding (4.5%). The common manure management practices during dry and rainy season included the collection of dung without urine at 39.20% and 36.60%, storing manure in the open at 38.60% and 36.90%, and composting at 85.40% and 87.70%, respectively in semi-grazing systems. The predominant crop residue could be targeted and manure management practice harnessed in a vibrant cottage industry to produce more refined products for the livestock feeds and household uses.

Keywords: Climate change, Environmental pollution, Greenhouse gas

Introduction

Crop residue is the fibrous by-product of crop harvesting that consists of plant elements such as roots, leaves, stalks, and peels with a variety of uses (Bhandari and Bahadur, 2019; Devi *et al*., 2017; Williams *et al*., 1997). The types of crop residues vary with the crops planted, farm practices, and household socio-cultural practices (Devi *et al*., 2017). Some of the common types of crop residues include stover from sorghum and maize, straw from wheat, rice, oats and barley, sugar cane tops or bagasse, bean haulms, and sunflower heads (Kahi and Wasike, 2019; Lukuyu *et al*., 2012). Crop residues are underutilized by farmers because they are perceived as waste with little economic benefit (Devi *et al*., 2017; Swidiq *et al*., 2012). The use of crop residues is also limited by its availability since crops are planted seasonally and inadequate knowledge of farmers on the uses and exploitation of crop residues Swidiq *et al*., 2012). However, if harnessed, crop residues are a vital

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agricultural resource globally with competing uses such as animal feeding and bedding, composting, mulching, and biogas production (Devi *et al*., 2017). Crop residue utilization practices play a significant role in management crop residue resources and practicing sustainable agriculture (Valbuena *et al*., 2015). The main determinants of crop residue utilization practices are biomass demand, resource availability, production levels, and farmers' preferences (Valbuena *et al*., 2015).

Waste from livestock systems comprises of dung, urine, bedding material, and water (Teenstra *et al*., 2015) which also varies depending on the livestock species kept. Waste from cattle systems is rich in nitrogen, phosphorous, potassium, and sulfur. When treated well, it forms nutrient-rich nature of manure that provides several advantages such as use as organic fertilizer which aids in plant development, reduced dependence on synthetic fertilizers, and addition of soil organic matter (Giosanu *et al*., 2022). Additionally, manure help in reducing the risk of soil erosion since it improves the water holding capacity of soil and it can also be used as a source of renewable energy for cooking, heating, and lighting when exposed to anaerobic digestion to produce biogas (Teenstra *et al*., 2015). Despite these advantages, the manure can also be a source of major environmental and public health challenges if neglected or not disposed properly (Giosanu *et al*., 2022). Improper management of manure can lead to greenhouse gas emission that is responsible for climate change and it can also lead to nutrient loss through soil infiltration or leaching thus leading to water pollution (Chadwick *et al*., 2011). The common manure management practices in dairy farms include collection, processing, handling, storage, and land application (Niles *et al*., 2019). The type of manure management practices to be adopted in dairy cattle production systems vary depending on the breeding system of the cows, the type of housing, the feeding system, and the size of the farm (*Niles et al*., 2019).

Studies have been done to identify how crop residue and manure management practices influence farm productivity and soil nutrient cycling in intensive and range systems in rural areas (Castellanos-Navarrete *et al*., 2015; Diressie, 2011; Meyer *et al*., 2011). However, these studies did not look at the utilization of crop residues and management practices of manure in peri-urban areas which are mainly dominated by semi-zero and zero-grazing systems. After establishment of devolved units and creation of grassroot administrative centre, Kenya has experienced exponential growth in its urban centres which have resulted in formally rural areas and farmlands becoming peri urban. Consequently, the scenario of farming systems in urbanized areas is becoming common place. This phenomenon presents environmental and social challenges such as air pollution, contamination of water ways and conflict between farming and non-farming households. Therefore, there is need to identify the existing crop residue utilization and manure management practices in the peri-urban regions to help in establishing proper and environmental-friendly crop residue utilization and manure management prctices that can promote sustainable agricultural practices. Establishing the status of CR utilization is essential in promoting the economic well-being of farmers, mitigating climate change, improving soil fertility, and promoting industries that deals with conversion of crop residues into useful products. In addition, establishment of manure management practices helps in reducing environmental, human health, and social challenges posed by manure. This study was the status of crop residue utilization and manure management practices in peri-urban dairy cattle production systems in Kisumu County, Kenya.

Materials and methods

Study area

The study was conducted in North West Kisumu and Central Kisumu Wards of Kisumu County which lies between longitude 34°46′E and latitude 0°06′S (Mireri, 2013). The annual minimum temperature ranges from 16^0C to 18^0C, while the annual maximum temperature ranges from 25^0C to 33^0C. The County receives an annual average rainfall of 450-600mm and 1000-1800mm during short rains and long rains, which come from September to November and March to May, respectively (County Government of Kisumu, 2018). The main economic activities practiced in the study area are fishing, trade, and farming. Mixed crop-livestock farming is the prevalent farming system where smallholder dairy farming under zero grazing and semi-zero grazing systems are predominant (Mireri, 2013). Crossbred cattle between exotic and indigenous are the common breed types although purebred Ayrshire, Friesian, and Guernsey exist (County Government of Kisumu, 2018). The type of crops that are commonly grown in the study area which are maize, beans, sorghum, sweet potatoes, and sugarcane (MoALF, 2018).

Data collection and analysis

The study adopted survey research design whereby questionairres were used for data collection. The reliability and validity of the questionnaires were tested by conducting a pilot study before the actual survey. The survey was conducted from 16th September 2021 to 9th October 2021 in North West Kisumu and Central Kisumu Wards of Kisumu County. During the survey, questionnaires were administerd by enumerators who were adequately trainned. The target population were households practicing mixed crop and dairy cattle farming. A sample size of 380 households were selected as survey respondents from a total of 30,560 households keeping dairy cattle in Kisumu West sub-county. The sample size was calculated using Fisher's formula proposed by Mugenda and Mugenda (2003):

$$\mathbf{nf} = \mathbf{n} \div \left(\mathbf{1} + \frac{\mathbf{n}}{\mathbf{N}}\right) \qquad \mathbf{nf} = \mathbf{384} \div \left(\mathbf{1} + \frac{\mathbf{384}}{\mathbf{30{,}560}}\right) = \mathbf{380\ households}$$

Where; **nf** = desired sample size when the population is less than 10,000, **n=** desired sample size when the population is more than 10,000 (384), **N=** estimate population size

A multistage sampling technique was used to randomly select the 380 respondents. Households practicing smallholder mixed crop-dairy cattle farming in Kisumu West Sub- County were first selected purposively. Thereafter a cluster of two wards was selected based on smallholder dairy cattle systems and solid waste management issues and the calculated sample size was proportionately distributed among the two wards from which the respondents were selected randomly. The questionnaire probed respondents on their household characteristics, farming system practices, types of crop residue and utilization practices (uses and treatment), and manure management practices (collection, storage, and treatment). The research adhered to the ethical codes of research during data collection by ensuring the participation in the research was free and voluntary. Informed consents were issued to the participants to promote their awareness of the benefits and risks of the research and the confidentiality and privacy of the participants were maintained by ensuring their personal details are not revealed in the study. Data were analyzed using descriptive statistics in Statistical Package for the Social Sciences (SPSS) software to obtain the means and percentages for the type, uses, and treatment of crop residues and manure collection, storage, and treatment.

Results

Characteristics of the farming systems

The type of cattle breed, herd size and land size in semi-zero and zero grazing dairy systems is presented in Table 1. Both purebred exotic and crossbred dairy cattle as well as indigenous cattle are kept on the farms. A larger number of local breeds (67%) are kept in semi-zero grazing farms while exotic breeds (40%) are mainly kept in zero-grazing farms. Cross breeds are present in both systems although in moderate numbers. It is also evident that a large percentage of the farmers keep small herd of cattle of < 4 and own small land parcels ranging from 1 to 3 acres of land.

Table 1. Available breed type, herd size, and land size in different production systems

Production System	Breed type	Farm units (No)	Farm units (percent)	Herd size	Farm units (No)	Farm units (percent)	Land size (acre)	Farm units (No)	Farm units (percent)
Semi-zero grazing	Local	692	67%	< 4	217	66%	< 1	96	29%
	Cross	301	29%	4 to 6	101	31%	1 to 3	225	68%
	Exotic	44	4%	> 6	11	3%	> 3	8	2%
Zero grazing	Local	46	37%	< 4	38	75%	< 1	9	18%
	Cross	28	23%	4 to 6	12	24%	1 to 3	39	76%
	Exotic	50	40%	> 6	1	2%	> 3	3	6%

Crop residue utilization practices

Crop residues observed in the semi-zero and zero grazing dairy systems are presented in Table 2. The prevalent crop residues found in the study area included green maize Stover, dry maize Stover, green maize cobs and kernel, banana residue, vegetable waste, sweet potato vines, dry maize cobs and kernel, and bean residue that were found in 40.70%, 16.80%, 13.50%, 6.40%, 6.20%, 5.00%, 3.50%, and 3.30% in semi zero grazing farms respectively. The other types of crop residue that were available although in few farms included cassava leaves, cow pea residue, groundnuts haulms, maize thinning, millet residue, oat residue, potato peelings, and sorghum residue. Similar crop residues were observed in the zero grazing dairy farms except cowpea residue, dry maize cob kernel Stover, groundnuts haulms, maize thinning, and sorghum residue.

Table 2. Available types of crop residue in the different production systems

Production system	Crop residue type	Farm units (No)	Farm units (percent)
Semi-zero grazing	Banana residue	31	6.40%
	Bean residue	16	3.30%
	Cassava leaves	4	0.80%
	Cowpea residue	5	1.00%
	Dry maize cob and kernel Stover	17	3.50%
	Dry maize Stover	81	16.80%
	Green maize cobs and kernel Stover	65	13.50%
	Green maize Stover	196	40.70%
	Maize thinning	4	0.80%
	Millet residue	4	0.80%
	Sweet potato vines	24	5.00%
	Vegetable waste	30	6.20%
	Others (Groundnut haulms, Oats straw, Sorghum residue, and Sugarcane tops)	4	0.80%
Zero grazing	Banana residue	9	12.50%
	Bean residue	2	2.80%
	Dry maize Stover	12	16.70%
	Green maize cobs and kernel Stover	6	8.30%
	Green maize Stover	31	43.10%
	Millet residue	2	2.80%
	Vegetable waste	6	8.30%
	Others (Cassava leaves, Potato peelings, Sugarcane toppings, and Sweet potato vines)	4	5.60%

The utilization of crop residues in the dairy systems. Crop residues were mostly used as livestock feed (55.9% and 48.5%), organic fertilizer (19.70% and 34.80%) and mulch (14.40% and 13.60%) in both semi-zero grazing and zero grazing, respectively (Table 3). A few semi-intensive and intensive farms was used crop residues for construction and livestock bedding. Use of crop residues as fuel and construction material were peculiar to semi-intensive systems.

Table 3. Crop residue uses and treatment methods in the different production systems

Production System	Crop residue uses	Farm units (No)	Farm units (percent)	Treatment method	Farm units (No)	Farm units (Percent)
Semi-zero grazing	Livestock feed	458	55.90%	Chopping	380	79.00%
	Livestock housing and bedding	37	4.50%	Grinding	1	0.20%
	Fuel	9	1.10%	No treatment	98	20.40%
	Construction Material	2	0.20%			
	Organic fertilizer	161	19.70%			
	Mulching	118	14.40%			
	Food additive	30	3.70%			
	Sold for income	4	0.50%			
Zero grazing	Livestock feed	64	48.50%	Chopping	61	84.70%
	Organic fertilizer	46	34.80%	No treatment	7	9.70%
	Mulching	18	13.60%			
	Food additive	2	1.50%			
	Others (Livestock housing and bedding, and Sold for income)	2	1.60%			

Various methods were used for treating crop residues in semi-zero grazing and zero grazing systems (Table 3). Chopping was the prevalent method of handling CR with 79% of the farm units in semi zero grazing units and 84.7% of the zero grazing units. The other types of treatment method that was observed in semi zero grazing was grinding which was only being done in one farm unit.

Manure management practices

The state in which the manure was during collection during the dry and rainy seasons in semi- zero and zero grazing dairy systems (Table 4). The largest percentage of farmers collected dung without urine in semi-zero grazing during dry season (39.2%) and rainy season (36.6%). In zero-grazing production systems, large percentage of farmers collected dung with feed leftovers and urine during dry season (51.0%) and rainy season (42.6%). A small percentage of the farmers collected urine separately in both systems.

Table 4. States of manure during collection, manure storage and treatment methods in semi-zero and zero-grazing dairy systems during the dry and rainy season

Production system	**Season**	**State of manure during collection**			**Manure storage methods**			**Manure treatment methods** *		
		Manure State	Farm units (No.)	Farm units (percent)	storage method	Farm units (No.)	Farm units (percent)	treatment method	Farm units (No.)	Farm units (percent)
Semi-zero grazing	Dry	Dung, Feed leftovers & urine	88	26.70%	Covered pits	31	9.40%	AD	1	0.30%
		Dung & Feed leftovers	103	31.30%	In the open	127	38.60%	Composting	281	85.40%
		Dung without urine	129	39.20%	No storage	34	10.30%	Drying	22	6.70%
		Others (Dung & urine and Urine separately)	9	2.70%	Open pits	48	14.60%	No treatment	25	7.60%
					Under the shade	89	27.10%			
	Rainy	Dung, Feed leftovers & urine	92	27.60%	Covered pits	38	11.40%	AD	2	0.60%
		Dung & Feed leftovers	107	32.10%	In the open	123	36.90%	Composting	292	87.70%
		Dung without urine	122	36.60%	No storage	39	11.70%	Drying	22	6.60%
		Others (Dung & urine and Urine separately)	12	3.60%	Open pits	43	12.90%	No treatment	17	5.10%
					Under the shade	90	27.00%			
Zero grazing	Dry	Dung, Feed leftovers & urine	26	51.00%	Covered pits	4	7.80%	Composting	46	90.20%

	Dung & Feed leftovers	7	13.70%	In the open	12	23.50%	No treatment	2	3.90%
	Dung & Urine	1	2.00%	No storage	5	9.80%	Others (AD, Drying, and SLS)	3	6.00%
	Dung without urine	17	33.30%	Open pits	9	17.60%			
				Under the shade	21	28.90%			
Rainy	Dung, Feed leftovers & urine	20	42.60%	Covered pits	3	6.40%	Composting	40	85.10%
	Dung & Feed leftovers	10	21.30%	In the open	10	21.30%	Drying	4	8.50%
	Dung without urine	17	36.20%	No storage	5	10.60%	Others (AD, and SLS)	3	6.40%
				Open pits	9	19.10%			
				Under the shade	20	42.60%			

*AD - Anaerobic digestion, SLS - Solid-liquid separation

Various methods of manure storage were observed in the study (Table 4). Keeping under the shade and in the open were the most preferred methods of manure storage across production systems and seasons. On the other hand, covering manure in pits was the least used method of manure storage on the farms. The largest percentage of farmers stored their manure in the open in semi-zero grazing during dry season (38.6%) and rainy season (36.9%). In zero-grazing production systems, largest percentage of farmers stored manure under the shade during dry season (28.9%) and rainy season (42.6%). The various methods of treating manure in semi zero and zero grazing dairy systems during the dry and rainy seasons respectively. Composting was the predominant method of manure treatment during the dry season (semi-zero grazing, 85.4%; and zero-grazing, 90.2%) as well as during the rainy season (semi-zero grazing, 87.7%; zero-grazing, 87.4%). A small percentage of the farm units treated manure by drying and using anaerobic digestion.

Discussion

Crop residue utilization practices

The prevalence of maize stover as a crop residue resulted that maize being widely cultivated as the stable food in the region (Marenya *et al*., 2021). Crop residues are a product of crop farming systems (Bhandari and Bahadur, 2019). Consequently, only crops farmed in a particular region would have their residues present in the farm units. Njarui *et al*. (2011) have reported high acreage of maize in the Machakos region relative to pigeon peas, beans, cowpeas, and green gram residues since the quantity that is being harvested is very low. A study by Devi *et al*. (2017) and Diressie (2011) reported prevalence for rice husks and teff straws in the farm units within the rice and teff belts of India and Ethiopia, respectively. The farm sizes in the study region are small thus limiting the farmers from planting various types of crops since the land is also allocated to other activities such as livestock rearing and construction. Mireri (2013) reported small land sizes in Kisumu Municipality limiting the farmers from planting various types of crops.

The available crop residues were mainly used as livestock feed as they were readily available with limited access to open grazing grounds. Furthermore, the use of crop residues as a feed resource was popular because commercial feeds are expensive and there are few alternatives to meet the surge in livestock feed demand (Bhandari and Bahadur, 2019; Valbuena *et al*., 2015). Crop residues, however, are high in fiber but low in nutrients; as a result, if fed to animals untreated, they may cause low digestibility, resulting in poor performance and productivity (Bhandari and Bahadur, 2019; Owen and Jayasuriyat, 1989). Crop residues were also being used as a cheap material for livestock housing, bedding, roof construction, food additives, and as mulch to conserve moisture, reduce soil evaporation, manage soil temperature, and enhance microbial activity as well as compost it to produce organic fertilizer that is suitable for enhancing soil fertility (Iqbal *et al*., 2020; Njarui *et al*., 2011). Several studies have identified crop residues as the main source of feed for cattle in smallholder dairy farms (Bhandari and Bahadur, 2019; Lukuyu *et al*., 2012). In contrast, Devi *et al*., (2017) identified that crop residues were mainly being used as fuel and burned on the farm to pave way for planting new crops.

The crop residues were being treated by chopping as it is cheaper and easier compared to grinding which is complicated and might require machines operated by electricity or fuel. Chopping primarily aids in reducing the residual size of crop residues hence making them less bulky, manageable, and easy to use. Chopping crop residue used as feed is crucial for increasing the surface area subjected to digesting enzymes in the animal body which helps in increasing feed intake and digestibility while limiting feed wastage (Bhandari and Bahadur, 2019). A study by (Mahesh and Mohini, 2014) reported an improvement in nitrogen level and digestibility of crop residue feeds when chopped to at least 2 to 3 cm.

Manure management practices

Manure was commonly collected in its solid form without urine as most of the farmers in the study housed the cattle in *bomas* or housing with bare ground thus making the collection of dung mixed with urine impossible. This is consistent with other authors. For instance, Aguirre-Villegas and Larson (2017) and Ndambi *et al*. (2019) also identified that most farmers had confinement systems with permeable floors making it difficult to collect urine. A significant supply of nitrogen and potassium throughout the nutritional transfer pathway is lost when urine is not collected (Snijders *et al*., 2013). Additionally, dung was collected with feed leftovers and urine in farms that fed the cattle in stalls since there were a lot of feed leftovers due to the high percentage of feed that was not being treated. Niles *et al*. (2019) identified that there was significant wastage of crop residue feed resulting from trampling when crop residues are thrown in the cattle *boma* (confinements) during the feeding of the cattle. Collecting dung mixed with feed leftovers helps to enhance the quality of manure by increasing the carbon-to-nitrogen (C/N) ratio, which aids in the reduction of nitrogen (N) losses during storage (Tittonell *et al*., 2010). When the quantity of leftovers gathered with dung is low, however, aerobic decomposition and associated N losses are simulated (Snijders *et al*., 2013).

The majority of the farmers stored the manure in heaps and pits which are simple and affordable methods for smallholder dairy farmers operating under minimal costs (Lupindu *et al*., 2012). Manure was not covered during storage but some farmers stored the manure under the shade. A tiny fraction of smallholder dairy farmers stored their manure in piles under a basic roof, shade, or covered with plastic due high cost of roof construction materials (Onduru *et al*., 2008). Storing manure in the shade can effectively deter rainfall from leaching nutrients from the manure because the shade reduces the quantity of water that gets into touch with the manure thus the likelihood of nutrient runoff is reduced (Lekasi *et al*., 2001). Moreover, roofing manure during storage enhances manure quality by lowering urine evaporation and preventing the loss of manure nutrients due to infiltration when it rains (Lekasi *et al*., 2001; Teenstra *et al*., 2015). Farmers that did not store manure applied it directly to the farm after collection which helps in reducing the loss of nitrogen (N) due to ammonia volatilization or run-off.

Composting was commonly used for treating manure since it is cheaper compared to other methods such as anaerobic digestion and solid-liquid separation which requires a lot of technical skills and high investment that smallholder farmers cannot afford (Ndambi *et al*., 2019). Composting makes manure less bulky for transportation and promotes nutrient uptake by plants from the soil when used as organic fertilizer. In addition, composting makes the resulting compost to be odorless and it also minimizes pests and diseases due to the high-temperature conditions (Ndambi *et al*., 2019). Furthermore, some farmers practiced drying manure to be used as fuel and fertilizer since it is simple and less labor-intensive. Anaerobic digestion and solid-liquid separation (SLS) techniques are also important manure treatment methods that were being used by very few farmers since they are costly and labour-intensive. Meyer *et al*. (2011) identified that most farmers treated manure using SLS, unlike the study's result. The difference is attributed to the difference in technological advancement and funds.

In conclusion, crop residue utilization and manure management practices are indispensable components of environmental protection and sustainable agricultural systems. Maize is widely grown in the study area leading thus leading to availability of maize Stover in large numbers. Crop are mainly used as livestock feed hence posing as a potential source of greenhouse gas emissions due to their low nutritional value and digestibility leading to air pollution and climate change. Embracing sustainable crop residue utilization practices is key in promoting reduced GHG emission and climate change, environmental sustainability, and resilient dairy farming systems. Crop residue utilization practices can be improved by value addition through silage making, composting, and mulching leading to increased dairy and crop productivity, use of chemical fertilizers, and environmental pollution. In addition, farmers can productively harness the potential of predominant crop residues in dairy farm systems by investing in cottage industries that can add value to the cop residues before they are utilized.

Efficient management of manure is substantial in optimizing nutrient recycling and protecting the environment. Implementing the appropriate manure collection, storage, and treatment methods can initiate reduced GHG emissions, water pollution, and nutrient runoff. Most farmers practice unsustainable manure management practices such as collection of dung without urine and not covering manure during storage which promotes loss of more nutrients due to rainwater and the emission of greenhouse gases. Adoption of appropriate manure management practices is hindered by lack of knowledge, high investment costs, and labour requirements. Creating awareness through farmer education, farmer trainings and workshops, agricultural shows and exhibition, and continued research can build the capacity of farmers to embrace sustainable practices and be innovative in developing technologies that are cost effective.

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