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Utilisation of cattle manure and inorganic fertiliser for food production in central Uganda

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Abstract : Cattle manure and inorganic fertiliser use in smallholder peri-urban crop-livestock farms in Uganda was investigated by conducting a survey of 40 farms in the central districts of Wakiso and Kampala. The results showed that the major benefits obtained from cattle manure application were increased yields (52.5 %) and low cost of manure purchase (37.5 %). The major problems associated with its use included weight and bulkiness (75 %), lack of labour (67.5 %), insufficient quantities (55 %), high transportation and application costs (37.5%), enhanced weed infestation (35 %), poor hygienic conditions (32.5 %) and lack of storage facilities to maintain quality attributes of manure (32.5 %). A large number of farmers supplemented the cattle manure with other animal manures, such as poultry (45 %), pig (38 %), goat (33 %) and rabbit (18 %) manures where available. The majority of farmers (95 %) never supplemented manure with inorganic fertiliser claiming that it was expensive in terms of purchase and transportation (90 %) and lack of capital to purchase the fertilisers (67.5 %). Farmers were aware of the benefits of using cattle manure as a source of fertiliser in their crop-livestock production system. However, the nutrient content of cattle manure was low (0.42-0.56 % total N), being attributed to poor handling, collection and storage of manure, insufficient fodder and poor livestock diet, which need better management to maximise nutrient recovery. There was little information available to farmers regarding optimum management and rates of fertiliser application (both inorganic and organic) to improve crop yields, which is required to improve food security and economic development in Uganda. Ugandan extension services should therefore make efforts to intensify education among farmers in relation to soil fertility management options. In addition, farmers should collect and store the manure properly and preferably in a covered pit to enhance

manure quality. Effective manure handling and storage systems should be designed that reduce loss of nutrients after excretion and during composting. Farmers should explore the viability of community based manure collection initiatives at the farm level where manure transportation costs are shared and hence minimized.

Keywords: cattle manure, fertiliser, smallholder farmers, urea.

Introduction

Minimal use of nutrient inputs in Sub-Saharan Africa (SSA) has contributed to a decline in soil fertility coupled with low crop yields (Kanonge *et al.*, 2009). This is a major constraint to food security and economic development in Uganda (Zake *et al.*, 2005). Many African soils are situated on very old continental plates (IITA, 2010) and coupled with low fertiliser use has aggravated the situation on the older and poorer soil types. The annual inorganic fertiliser application rate in Uganda is less than a kilogram of nutrients per hectare, which is insufficient for intensive food production in the longer term (NARO and FAO, 1999). Consequently, many farms suffer from negative nutrient imbalances (Nkonya *et al.*, 2002; Zake *et al.*, 2010). The average fertiliser application for SSA at 9 kg ha^{-1} is only 5 % and 20 % of that used in East Asia and Latin America, respectively (Panda, 2008). Snapp *et al.* (1998) recommended that management for the use of cattle manure be improved to increase food production, since it is a major soil amendment used by smallholder farmers in SSA. However, there is little data available about the use of cattle manure as a source of nutrients to improve soil fertility to sustain crop growth and increase food production where inorganic fertiliser supply is constrained (Muhereza, 2005). The aim of this study was to assess the utilisation of cattle manure and inorganic fertilisers in smallholder crop-livestock farms in central Uganda.

Materials and Methods

A survey of 40 smallholder farms was conducted in densely populated peri-urban areas comprising Bikka and Nangaabo sub-counties in Wakiso and Kawempe and Lubaga divisions in Kampala during 2010. These locations are characterized by well-established peri-urban agriculture with smallholder farmers accounting for more than 80 % of the population (Maxwell, 1995; Ssembalirwa, 2008). Crop cultivation, livestock rearing and fish farming are the main activities (Atukunda *et al.*, 2003). These areas experience moderate average temperatures, slightly above 20 °C and receive a bimodal annual average rainfall above 1,320 mm (MWE, 2011).

The participants selected for the study had farms that ranged between 0.5 and 2.0

ha in size, derived the majority of food and income from the farm, and applied cattle manure to their gardens in the production of selected crops (cabbage and dodo). Purposive, stratified and random sampling methods were used to obtain the mutually exclusive group (Peil, 1995). The survey was conducted over a period of two weeks using semi-structured interviews, focus group discussions and field observations. The survey study design was cross-sectional and descriptive to determine the methods of cattle manure application, storage and handling techniques and reasons for non-use or limited use of inorganic fertiliser. Eight samples of cattle manure from farms in the study area were collected for nutrient analysis including aged manure (heaped for more than 1 year), fresh manure (collected inside the kraal), uncovered manure and biogas slurry. Total nitrogen (N) was measured using the combustion method and total phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), sulphur (S), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) were measured by ICP-AES at Makerere University, Kampala, Uganda.

Primary data was collected using a pre-tested, structured questionnaire with each farmer, which included: farmer characteristics (age, farming experience), type of farming system, enterprise promoted by the farmer, farm size, type of livestock reared by the farmer, methods of manure application used by farmers, benefits of cattle manure application, reasons for non-use of fertilisers, quantity of manure applied, crops where manure is applied, labour availability and yield data, crop husbandry practices, and problems and constraints encountered in crop production. The study captured both qualitative and quantitative data in order to obtain in-depth analysis in a structured way. In addition to the questionnaire, focus group discussions were held to verify some of the information completed in the questionnaires and to get more views and perceptions on manure use including the factors influencing its application and quantity of manure produced per day.

Data collected was entered into Excel spreadsheets and then simple univariate analysis carried out using SPSS to generate simple statistical information, which included frequency distributions for the different variables of the study. The content analysis method was used to analyse qualitative data. Categories for the open-ended questions were developed to be mutually exclusive and exhaustive based on themes that emerged from the replies during the study. However, discreet single categories were in other cases combined into more general categories to enable cross tabulation.

Results

Demographic characteristics and farming enterprises in the study area

The 40 respondents were all smallholder farmers whose livelihood largely depended on crop-livestock farming with 25 men (62.5 %) and 15 women (37.5 %)

Table 1 - Age characteristics and marriage status of the respondents by gender.

Characteristics	<35 years		>35 years	
Age by gender	Count	%	Count	%
Male	9	36	16	64
Female	6	40	9	60
Marriage status by gender				
Male married	6	24	13	52
Male single	3	12	3	12
Female married	4	26.7	8	53.3
Female single	2	13.3	1	6.7

n=25 for men and 15 for women

Table 2 - Mean farm size and utilisation by smallholder crop-livestock farmers.

Men enterprises	Count	% of respondents by gender	Farm size (ha)	% land allocated
Pasture	22	88	0.20	11.8
Cabbage	20	80	0.20	11.8
Dodo	16	64	0.13	7.7
Bananas	14	56	0.44	26.0
Cover crops	12	48	0.12	7.1
Maize	12	48	0.60	35.5
Women enterprises				
Beans	15	100	0.07	6.9
Dodo	15	100	0.19	18.8
Potatoes	15	100	0.40	39.6
Cabbage	13	86.7	0.30	29.7
Ground nuts	9	60	0.05	5.0
Pastures	0	0.0	0.0	0.0

(n=25 for men and 15 for women)

interviewed. The majority of male farmers (64 %) and female farmers (60 %) were more than 35 years of age (Table 1). There were relatively few single farmers; the majority of all respondents in all age groups were married.

Table 2 shows the major enterprises carried out by different categories of farmers in the study based on gender. There was a preference for growing pasture (88 %) and cabbage (80 %) amongst the men, though the largest percentage of land area was allocated to bananas (26 %) and maize (35.5 %). In comparison, 100 % of the women grew beans, dodo and potatoes, with most of the land area dedicated to potatoes and cabbage.

Cattle manure use by smallholder farmers

All the farmers in the study applied cattle manure (100 %). The major benefits obtained from the use of cattle manure included increased crop yields (52.5 %), disease reduction (30 %) and low cost of purchasing the manure (37.5 %). The least mentioned benefit was biogas as a source of energy (7.5 %). Farmers fertilised portions of the farm on a rotational basis according to perceived soil nutrient deficiency. A total of 22 farmers (55 %) indicated that cattle manure was not adequate to fertilise the whole farm in a single cropping season. The farmers attributed the inadequacy of manure to small herd size on the limited land available (88 %) and/or inadequate fodder (69 %). The source of cattle manure used by farmers was varied. The majority of farmers collected manure solely from their own animals (55 %), while 46 % purchased the manure and 22 % collected manure from the neighbours.

The average concentration of nutrients in the four types of cattle manure collected from farms in the region is summarized in Table 3. The concentrations of plant nutrients varied between the different forms of manure. The concentration of total N in fresh cattle manure collected during the survey was 0.56 % and declined to 0.44 % for uncovered manure and to 0.42 % in aged manure. Highest concentrations of total N were measured in biogas slurry (0.60 %). The concentrations of Total P and K also varied and were 0.18 and 0.51 that reduced to 0.15 and 0.40, respectively.

Table 3 - Nutrient contents of cattle manure used in the area on dry weight basis.

Type of manure	N	P	K	Ca	Mg	Mn	Cu	Fe	Zn
	---------- percent----------					---------- mg kg^{-1} ----------			
Fresh manure	0.56	0.18	0.51	0.19	0.10	28.6	1.51	58.4	0.75
Uncovered fresh	0.44	0.15	0.40	0.16	0.12	38.4	1.24	71.6	0.62
Aged manure	0.42	0.28	0.45	0.22	012	24.2	2.14	52.5	0.84
Biogas slurry	0.60	0.22	0.52	0.23	0.09	32.3	1.12	62.6	0.96

Source: Makerere University Laboratory Report 2010, based on two samples of each type on DM basis

Cattle manure handling and application methods

The various methods of manure handling in the area included composting (35 %), covering (27.5 %), uncovered manure (55 %), providing shade with tree branches or under a temporary constructed shelter on heaped manure (15 %) and direct application to crops (25 %) (Table 4). Cattle manure was either heaped temporarily outside the housing unit or applied directly to the field to minimize nutrient losses. The manure was also often mixed with ash (37.5 %), crop residues (35 %), or animal beddings (30 %) (Table 4). The reasons identified for mixing manure, included faster decomposition (37.5 %), increased volume of manure produced (27.5 %), and odour

Table 4 - Handling methods of cattle manure employed by farmers.

HANDLING METHODS	COUNT	% OF RESPONDENTS
Compositing	14	35.0
Covered manure	11	27.5
Un-covered manure	22	55.0
Under shade	6.0	15.0
Mix cattle manure with ash	15	37.5
Mix manure with crop residues	14	35.0
Mix cattle manure with animal beddings	12	30.0

(n=40; more than one answer was allowed)

Table 5 - Application methods of cattle manure by farmers.

METHOD OF CATTLE MANURE APPLICATION	COUNT	% OF RESPONDENTS
Heap around the crop	18	45.0
Apply in trenches and cover with soil	13	32.5
Broadcast to the soil surface and don't cover	23	57.5
Apply in holes before planting cabbage	12	30.0

(n = 40; more than one answer was allowed)

reduction (37.5 %), while 52.5 % followed the advice from technical personnel in the area.

Cattle manure was predominantly applied in its solid form by 90 % of farmers due to its ease of transport to the garden and application, while 35 % of farmers applied cattle urine. Manure tea was the least applied as it required large containers, which were expensive. The most common method used by farmers to apply manure to crops was to broadcast it on the soil surface without covering (57.5 %), or to heap the manure around the crop regardless of whether it was fresh or composted (45 %). Some farmers applied manure in trenches and covered it with soil (32.5 %), whereas 30 % placed the manure in holes and left them open for a while before planting, particularly for cabbage (Table 5).

Cattle manure application was concentrated on plots near the homestead (55 %). However, during the dry season, 15 % of farmers applied cattle manure to plots farther from the homestead when it was easier to transport than in the wet season.

Problems of cattle manure use by smallholder farmers

Although manure application to crops was credited for its associated benefits, the majority of respondents mentioned that it was bulky to apply (75 %) and that they often lacked the labour to apply it (67.5 %) or could not obtain sufficient quantities (55 %). Other problems with its use included enhanced weed infestation (35 %), poor

Table 6 - Problems of cattle manure application.

Problems	Count	% of respondents
Bulky	30	75.0
Lack of labour	27	67.5
Insufficient manure	22	55.0
Weed infestation	14	35.0
Poor hygienic conditions	13	32.5
Bad odour	10	25.0
Presence of pests	9.0	22.5
Scorched plants	7.0	17.5
Transport and application costs	15	37.5
Lack of manure storage facilities	13	32.5
Chaffer grubs	11	27.5

(n = 40; more than one answer was allowed)

hygienic conditions (32.5 %), bad odour (25 %), host for various pests (22.5 %) and scorching of plants (17.5 %), high transportation and application costs (37.5 %) especially during the rainy season due to poor roads and heightened by rising fuel prices, lack of storage facilities (32.5 %) to maintain quality attributes, and the incidence of chaffer grubs and worms (27.5 %) which are a nuisance during application, in addition to reducing crop growth (Table 6).

Use of other manures and inorganic fertiliser

The study indicated that 45 % of the farmers supplemented cattle manure with poultry manure, 33 % used goat manure, 38 % pig manure, but in limited quantities because of low availability, and 18% used rabbit manure. Only 5 % of farmers surveyed used inorganic fertiliser (urea) in addition to cattle manure. The major reason given by the non-users of inorganic fertiliser was the expense in terms of purchase and transportation (90 %) and lack of capital to purchase the fertilisers (67.5 %). Other reasons for non-use included perceived soil nutrient exhaustion (45 %), the continuous use of fertiliser to sustain crop productivity (42.5 %) and lack of knowledge of application rates and inaccessibility (30 %) (Table 7).

Focus groups meeting issues

The four focus group meetings conducted with smallholder crop-livestock farmers that participated in the study provided detail on a range of issues (Table 8). The production of cattle manure was low as a result of lack of supplementary feeding and fodder due to limited land and low herd numbers. Farmers commented that they

Table 7 - Reasons given by farmers for non-use of inorganic fertilisers.

Item	Count	% of respondents
Expensive to purchase and transport	36	90.0
Lack of capital	27	67.0
Their use exhausts soil fertility	18	45.0
They require continuous application once used	17	42.5
Lack knowledge on application rates and inaccessible	12	30.0
Their use increases soil acidity	10	25.0
They affect the health of human beings	8	20.0

(n = 40; more than one answer was allowed)

lacked information on manure quantity produced per day when animals were grazing on pasture. Some farmers who kept dairy cattle applied the manure to crops to dispose of it, rather than use it as fertiliser. Many farmers were reluctance to use and/or buy cattle manure, especially on rented land. This was most evident amongst the men who were often involved in off-farm activities. Factors influencing the use of cattle manure included off-farm income for salaried workers but who also do farming, awareness of the benefits of fertilisers, farm characteristics of land tenure, location and expectations to continue farming on rented land. Concerns with the use of inorganic fertiliser included its marketing and distribution being influenced by poverty and politics (Table 8).

Table 8 – Issues that emerged during focus group discussion.

Issue	Farmer responses/reasons
Farmers' reluctance to use and or buy cattle manure	Farmers' use of rented land Manure may not be beneficial in one season Manure smells
High yields realized with manure application	When incorporated in the soil or in trenches When well decomposed
Low manure production	No supplementary feeds to animals Insufficient fodder to feed animals
Men not willing to apply manure	It takes too long to realise effects of manure Involved in other off farm activities
Marketing and distribution of fertiliser	Influenced by poverty and politicians Do not know
Socio economic factors influencing cattle use	Off-farm income Awareness of the benefits of fertilisers Farm characteristics of land tenure Location Expectations to continue farming Farming on rented land

Discussion

Cattle manure use by smallholder farmers

Cattle manure is a valuable source of plant nutrients to meet N, P and K requirements in Uganda (Ngambeki and Rubaihayo, 1993). This study highlighted the use of cattle manure as the primary fertiliser in peri-urban smallholder crop-livestock production systems in Wakiso and Kampala districts in central Uganda. This is consistent with the findings of Mugisa (2002) and Muhereza (2005), which established that animal manure is widely used to improve crop yields. Wabudeya (1996) found yield benefits among zero grazing dairy farmers in Mbale, eastern Uganda. Mureithi *et al.* (1996) reported that manuring increased yields of maize grain and stover. In effect, animal manure is an asset for transferring plant nutrients from feeding to crop areas, thus keeping land fertile (de Wit *et al.*, 1997). Many farmers claimed that cattle manure improved crop growth. Currently cattle manure is being applied by farmers in Wakiso and Kampala with minimal knowledge of their nutrient status, and hence the nutrients required for optimal crop growth may be insufficient.

This study showed that cattle manure used by farmers was relatively low in nutrient value and averaged 0.47 % N, 0.20 % P and 0.45 % K on dry weight basis for six samples of cattle manure collected in the study comprising fresh, aged and uncovered cattle manure. Elsewhere, in SSA, FAO (2001) measured a higher concentration of N in fresh cattle manure (1.4%). Similarly higher levels of total N (1.4 %) on dry matter (DM) basis were reported in Kenya by Lekasi *et al.* (2001) and Onduru *et al.* (2008), comprising fresh dung, slurry, manure based compost, a composted mixture of dung, urine, feed refusals and bedding and 2.1 % N reported in cattle manure slurry by Snijders *et al.* (1992). In the United Kingdom and India, similar and higher values for these nutrients have been reported by Defra (2001), Smith *et al.* (2003), Rigby (2008) and Kumar and Shivay (2008) due to improved diet and or supplementary feeds given to animals and genetic differences. The quality and quantity of fodder fed to livestock can affect the proportion of N in manure (Powell *et al.*, 1994; Romney *et al.*, 1994).

Sizes of plots of land owned by farmers in peri-urban areas in SSA are increasingly becoming smaller (Atukunda *et al.*, 2003; Ssembalirwa, 2008). This coupled with lack of fodder and non-provision of supplementary feeds due to lack of capital, result in less cow dung with low nutrient contents leading to low levels of crop yields. Katuromunda *et al.* (2012) found that the nutrient concentrations of N, P and K from composted manure are low but N levels improve when the cattle diet is supplemented with Calliandra. The nutrient content of cattle manure in Uganda will remain low, whilst the livestock diet is limited. In addition, farmers were unable to source adequate quantities of cattle manure to fertilise the entire farm in a single season due to low herd numbers.

Farmers mostly used their own manure, but some farmers obtained it for free or purchased it from neighbours, as quantities of their own manure were not adequate. Farmers were reluctant to buy cattle manure for use on rented land, as manure was not considered beneficial for one season's rental. There was a difference between gender responses with many men not willing to apply cattle manure; and some commented on the length of time required to gain satisfactory crop response. Men didn't see the point in applying manure to benefit the owner of the land or the next farmer in the subsequent seasons. Women were more willing to apply cattle manure to obtain higher yields as they were responsible for preparing meals and the low crop yield disadvantaged them directly. However, farmers who rented large plots of land were willing to apply more manure but reiterated that transport was a big issue, in addition to temporary land ownership.

Cattle manure handling and application methods

The nutrient content of cattle manure was worsened by lack of suitable on-farm storage facilities. Leaving manure uncovered in a heap was the most common storage method, although some farmers were providing shade to heaped manure, while others were applying it directly to crops. In order to optimize and maintain manure quality, it is necessary to minimize nutrient loss during manure collection, storage and utilization (Chadwick *et al.*, 2000). High variability of manure N content has been reported in the savannah areas of West Africa (Tarawali *et al.*, 2004; Abunyewa *et al.*, 2007) and in East Africa (Onduru *et al.*, 2008). This was attributed to the climatic and handling effects on manure. Results showed that covering cattle manure is not a widely adopted practice by farmers in the study area, despite being promoted by the Kulika charitable organisation trust, an NGO promoting organic farming in the area. The main reasons for not covering manure were lack of covering materials (vegetative materials mostly) and limited labour in the area. Katuromunda *et al.* (2012) established that storage methods affect the quality of manure and concluded that storing cows faeces in pits and leaving the pits open was the most appropriate and low cost management intervention for improving cattle manure nutrient conservation. Farmers in this study did not use storage pits. Most cattle kraals in Uganda are not roofed and have no bedding to absorb urine. Manure and urine are thus exposed to high temperatures and rainfall throughout the year, which contribute to the loss of nutrients (Lekasi *et al.* 2003; Abunyewa *et al.*, 2007). Therefore, improving manure collection and storage should increase the manure quality.

The most common application method for cattle manure in the study area comprised spreading it on the soil surface without covering. Some farmers heaped manure around the crop whereas others applied manure in trenches and covered it with soil. The effectiveness of manure as fertiliser/soil amendmentis often limited by

its poor quality (low nutrient content) compounded by the immobilization of N due to high C: N ratios during early plant growth (Nyamangara *et al.*, 2003; Nyamangara *et al.*, 2009). Another problem with the use of manure is that it contains weed seeds, pests and diseases, which decrease the performance of crops. In particular, chaffer grubs and worms destroy vegetable seedlings, especially cabbages. Farmers have been advised to compost their organic manures including cattle manure prior to application (Eghball and Gilley, 1999). Composting of cattle manure is expected to kill weeds and other pathogens resulting in healthier crops. Manure applied when still fresh was responsible for the scorching of plants, hence the reason for a withholding period and storage. Farmers noted that when manure was incorporated in the soil or in trenches, crop yields were increased

A small number of farmers made 'manure tea', which was promoted in the study area as a fertiliser. This was prepared by placing a mixture of manure and water in a container and stirring thoroughly with a stick. However, manure tea production requires water, which is expensive in the area, particularly in the Kampala peri-urban area. This study did not analyse the manure tea for nutrients, but would be expected to be dependent on the inputs and dilution rate. Further research is required to ensure that guidelines are developed for the use of manure tea. A few farmers also collected and used urine because of its ease of application, particularly in vegetables.

Problems associated with cattle manure application by smallholder farmers

The main problems identified with the use of cattle manure were its bulkiness and the associated difficulty in transporting it to the point of application, which were also reported by Pali (2003). Lack of labour was a common problem experienced by many farmers and also reported in peri-urban areas in Kenya by Lekasi *et al.* (2003). The shortage of labour could explain why many farmers gave away their cattle manure freely to neighbours. Family labour is commonly used for most agronomic activities, including manure application; perceived by farmers to be cheap as it does not involve a direct cash outlay. The opportunity cost for labour needs to be calculated considering the fact that the study area was close to the capital city, Kampala. Other problems that were reported to be associated with the use of cattle manure included its bad odour, although respondents noted that the smell of manure bothered neighbours more than themselves. Lekasi *et al.* (1998) observed that such smells were attributed to poor storage and handling techniques of cattle manure.

Use of other manures and inorganic fertiliser

Besides the application of cattle manure for crop growth, many farmers supplemented cattle manure with other types of animal manure including goat, pig,

chicken and rabbit manure. The choice of manure was based on availability. Rabbit and chicken manures were considered practical and require less labour as they were less bulky, due to a lower moisture content and ease of drying. However, given that there are lower numbers of these animals, the manure quantities from them are limited.

Only a few farmers (5 %) applied inorganic fertiliser (urea) to their crops. This was mostly attributed to its cost. For example, in Uganda and throughout much of SSA, a kilogramme of NPK costs about 1 US$, while Diammonium phosphate (DAP) is even more expensive. Therefore, smallholder farmers cannot afford inorganic fertilisers. It has been established that the limited availability of inorganic fertilisers contribute to low yields in SSA, including Uganda (Kanonge *et al.*, 2009). Thus, there is urgency to make better use of inorganic fertiliser options to improve soil fertility. The use of inorganic fertilisers and other soil amendments has been regarded as essential to increase crop production and productivity (Rufino *et al.*, 2006; Panda, 2008). Uganda lags behind most SSA countries in inorganic fertiliser use, applying below 1,000 tons per annum (Jayne *et al.*, 2003).

It has been argued by some researchers that the limited adoption of fertiliser use in SSA is due to lack of subsidies, poor market infrastructure, and management related constraints (IFDC, 2003; Howard *et al.*, 2000). Lack of capital, soil exhaustion and the need for continuous application were mentioned as additional limiting factors to inorganic fertiliser use by respondents in this study; however, it was noted that higher returns could be obtained from inorganic fertiliser use. Compared to the use of cattle manure, the labour for applying, loading and transporting cattle manure would be more costly than for inorganic fertiliser application due to its bulky nature. The costs for chemicals and spraying equipment for the resultant weeds under cattle manure would also be higher compared to inorganic fertiliser application.

Although, cattle manure will contribute to the improvement of soil fertility and productivity if well conserved and recycled on smallholder farms, it does not supply plants with sufficient amounts of nutrients (Lekasi *et al.*, 2001; Katuromunda *et al.*, 2011). Therefore, the strategic application of cattle manure in combination with inorganic fertilisers would be a better option. It has been reported in India, that when supplemented with inorganic fertilisers, four cows could produce sufficient manure to fertilise one hectare of crop, usually applied once every two years (Singh, 1978). Katuromunda *et al.* (2011) reported that a cow with an average live weight of 504 + 61 kg can excrete 4.6 kg DM of faeces per day with an annual output of 1,679 kg DM. In their study it was established that cows supplemented with Calliandra, Centrosema and Desmodium species excreted 4.87 kg, 4.75 kg and 4.46 kg of DM per day, respectively. However, prior to the application of any inorganic fertiliser, it is essential to have a sound understanding of the main nutrient limitations to crop production on peri-urban smallholder farms in Uganda. Therefore, rigorous soil and plant

sampling and analysis are required to identify nutrient deficiencies in order to target the correct type and rate of fertiliser required.

Conclusions and recommendations

Smallholder farmers were aware of the benefits of fertiliser use (inorganic and organic), with cattle manure being used as a major source of nutrients in their crop-livestock production systems. The nutrient concentrations of cattle manures commonly applied were found to be relatively low. The low values were attributed to the diet of cattle, which if improved would improve manure quality. The difficulty in obtaining large quantities of cattle manure coupled with high costs of transportation and less mechanized application limit the use of cattle manure for food production.

Farmers should endeavour to collect and store the manure properly and preferably in a covered pit to enhance manure quality. It is not advisable to apply fresh cattle manure to crops due to scorching of crops; hence the aged manure with a lower nutrient content is applied. There is need to design effective manure handling and storage systems that reduce loss of nutrients after excretion and during composting, and to explore the viability of community based manure collection initiatives at the farm level where manure transportation costs are shared and hence minimized. Farmers should capture urine, as it assists in decomposition of the waste heap.

There is need to identify soil nutrient constraints common to different farming regions in Uganda to optimize fertiliser application decisions, particularly for the addition of inorganic fertiliser, such as urea. The Ugandan government and the local administration units should make efforts to intensify education among farmers in relation to soil fertility management, cattle manure timing of application, placement methods, rates and the combined use of manure and inorganic fertilisers to maximise crop yields, boost farmer economies of scale and provide better food security for Ugandans.

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References

Abunyewa A. A., Osei C., Asiedu E. K., and Safo E.Y., 2007. Integrated Manure and Fertiliser Use, Maize Production and Sustainable Soil Fertility in Sub Humid

Zone of West Africa. Journal of Agronomy 6(2): 302-309.

Atukunda G., Baseke F., David S., Jagwe J., Kalyebara M., Kaweesa M., Miiro R., 2003. Farming in the City: Participatory Appraisal of Urbana and Peri-Urban Agriculture in Kampala, Uganda. CIAT Africa Occasional Publications Series, No. 42. CIAT, Kampala, Uganda.

Chadwick D. R., John F., Pain B. F., Chambers B. J., and Williams J., 2000. Plant Uptake of Nitrogen from the Organic Nitrogen Fraction of Animal Manures: A Laboratory Experiment. The Journal of Agricultural Science 134(02): 159-168.

Defra (Department of Environment, Food and Rural Affairs, (2001). Managing Livestock Manures. Making Better Use of Livestock Manures on Arable Land. Booklet 2.Notts, UK: ADAS.

De Wit J., Van Keulen H., Van der Meer H. G., and Nell A. J., 1997. Animal Manure: Asset or Liability? World Animal Review 88 (1) 30-37.

Eghball B., and Gilley J. E., 1999. Phosphorus and Nitrogen in Runoff following Beef Cattle Manure or Compost Application. Alliance of Crop, Soil and Environmental Science Societies

FAO, 2001. Soil and Nutrient Management in Sub-Saharan Africa in Support of the Soil Fertility Initiative. A Paper read at Proceedings of the Expert Consultation, Lusaka, Zambia 6-9 December 1999.

Howard J., Jeje J., Kelly V., and Boughton D., 2000. Comparing Yields and Profitability in Mader's High-And Low-Input Maize Program. Maputo, Mozambique: Government of Mozambique, Ministry of Agriculture and Rural Development. Research Report 39.

IITA (International Institute of Tropical Agriculture), 2010. Made to Measure: Smart Natural Resources Management Approaches. Research Review for Development. IITA publication. http://r4dreview.org/2010/03/made-to-measure-smart-natural-resources-anagement-approaches

IFDC (International Fertilizer Development Centre), 2003. Input Subsidies and Agricultural Development: Issues and Options for Developing and Transitional Economies. Muscle Shoals, Al: International Fertiliser Development Centre. Paper Series P-29.

Jayne T.S., Kelly V., and Crawford E., 2003. Fertiliser Consumption Trends in Sub-Saharan Africa. Policy Synthesis. Number 69. Africa Bureau Office of Sustainable Development and Bureau for Economic Growth, Agriculture and Trade and Office of Agriculture Food Security.

Kanonge G., Nezomba H., Chikowo R., Mtambanengwe F., and Mapfumo P., 2009. Assessing the Potential Benefits of Organic and Mineral Fertiliser Combinations on Maize and Legume Productivity under Smallholder Management in Zimbabwe. Paper read at African Crop Science Conference Proceedings.

Katuromunda S, Sabiiti E. N., and Bekunda A. M., 2012. Effect of method of storing cattle faeces on the physical and chemical characteristics of the resultant

composted cattle manure. Uganda Journal of Agricultural Sciences, 2012, 13 (2): 95-106; Retrieved June 4, 2014, from http://www.naro.go.ug/UJAS/Papers/UJAS%20vol.13.2/UJAS%2095.pdf

Katuromunda S., Sabiiti E. N., and Bekunda M.A., 2011. Effect of combined application of cattle manure and mineral fertilisers on the growth characteristics and quality of *Pennisetum purpureum* fodder. Livestock Research for Rural Development. Volume 23, Article #251. Retrieved June 4, 2014, from http://www.lrrd.org/lrrd23/12/katu23251.htm

Kumar D., and Shivay Y. S., 2008. Modern Concepts of Agriculture. Integrated Crop Management. Accessed on 4th August 2011 from http://nsdl.niscair.res.in/bitstream/123456789/679/1/revised+integrated +rop+management.pdf

Lekasi J. K., Tanner J.C., Kimani S. K., and Harris P. J. C., 1998. Manure Management in the Kenya Highlands: Practices and Potential, Pp1-35. The Henry Doubleday Research Association. UK: HDRA, Ryton Organic Gardens.

Lekasi J. K., Tanner J.C., Kimani S. K., and Harris P. J.C., 2001. Manure Management in the Kenya Highlands: Practices and Potential. Kenilworth, UK: HDRA.

Lekasi J. K., Tanner J.C., Kimani S. K., and Harris P. J.C., 2003. Cattle Manure Quality in Maragua District, Central Kenya: Effect of Management Practices and Development of Simple Methods of Assessment. Agriculture, Ecosystems & Environment 94(3):289-298.

Maxwell D.G., 1995. Labour, Land, Food and Farming: A Household Analysis of Urban Agriculture in Kampala, Uganda. Ph.D. Thesis. University of Wisconsin, Madison, USA.

Mugisa T. K., 2002. Integration of Forage Legumes into Per-Urban Maize and Elephant Grass Systems in Kampala-Jinja Milk Shed: MSc. Thesis. Makerere University, Kampala, Unpublished.

Muhereza I., 2005. Socio-economic Evaluation of Cattle Manure Application in Peri-urban Farming Systems: MSc. Thesis. Makerere University, Kampala. Unpublished.

Mureithi J. G., Jayler R.S., and Thorpe W., 1996.Effects of the Application of Dairy Cattle Slurry and Intercropping with Cowpea on the Performance of Maize in Coastal Low Land Kenya. African Crop Science Journal 4(3): 315-324.

MWE (Ministry of Water and Environment), 2011. Review of Rainfall Performance for the Past Season (June to August) and Seasonal Climate Outlook for September to December 2011. Entebbe: Ministry of Water and Environment, Department of Meteorology. http://www.necjogha.org/news/2012-03-08/uganda-releases-seasonal-forecast-march-april-may-2012. Accessed 2nd October 2011.

NARO (National Research Organization), FAO (Food and Agriculture Organization), 1999. Fertility initiative concept paper. Ministry of Agriculture Animal Industry,

and Fisheries, Kampala, Uganda. pp. 3-8.

Ngambeki D. S., and Rubaihayo P. R., 1993. An Economic Analysis of Banana Production in Uganda. Paper presented at the first crop science conference for Eastern and Southern Africa, 14-18 June 1993, Kampala, Uganda.

Nkonya E., Pender J., Sserunkuuma D., and Jagger P., 2002. Development Pathways and Land Management in Uganda: In Policies for Sustainable Land Management in the East African Highlands. Paper presented at the Conference on Policies for Land Management in the East African Highlands, United Nations Economic Commission for Africa (ECA), Addis Ababa, Ethiopia.

Nyamangara J., Mtambanengwe F., and Musvoto C., 2009. Carbon and Nitrogen Mineralisation from Selected Organic Resources Available to Smallholder Farmers for Soil Fertility Improvement in Zimbabwe. African Journal of Agricultural Research 4: 870-877.

Nyamangara J., Piha M. I., and Giller K. E., 2003. Effect of Combined Cattle Manure and Mineral Nitrogen on Maize N Uptake and Grain Yield. African Crop Science Journal 11 (4):289-300.

Onduru D. D., Snijders P., Muchena F. N., Wouters B., DeJager A., Gachimbi L., and Gachini G. N., 2008. Manure and Soil Fertility Management in Sub-Humid and Semi-Arid Farming Systems of Sub-Saharan Africa: Experiences from Kenya. International Journal of Agricultural Research 3(3): 166-187.

Pali P. N., 2003. The Profitability and Acceptance of Alternative Soil Improvement Practices in Tororo District. MSc Thesis. Makerere University, Kampala, Uganda. Unpublished.

Panda S. C., 2008. Soil Conservation and Fertility Management. Jodhpur. India: Agrobios (India).

Peil M., 1995. Socio Science Research Methods. A Handbook for Africa. 2ndRevised Edition. Nairobi: East African Education Publishers Ltd.

Powell J. M., Pearson R. A., and Hiernaux P. H., 1994. Crop-Livestock Interactions in the West African Dry Lands. Agronomy Journal 96: 469-483.

Rigby H., 2008.Quantifying the Agronomic Value of Biosolids and Biowastes. PhD Thesis". Imperial College, London, UK. Unpublished.

Romney D.L., Thorne P. J., and Thomas D. R., 1994. Some Animal-Related Factors Influencing the Cycling of Nitrogen in Mixed Farming Systems in Sub-Saharan Africa. Agriculture Ecosystem and Environment 49: 163-172.

Rufino M. C., Rowe E. C., R Delve. J., and Giller K. E., 2006. Nitrogen Cycling Efficiencies through Resource-Poor African Crop-Livestock Systems. Agriculture, Ecosystems and Environment 112 (4): 261-282.

Smith S. R., Morris R., Bellett-Travers D. M., and Bell J. N. B. 2003. Managing the Phosphate Supply from Sewage Sludge Amended Agricultural Soil. Paper read at Proceedings of the Joint CIWEM and Aqua Enviro Technology Transfer. 8th

European Biosolids and Organic Residuals Conference, 24-26 November, Wakefield, UK.

Singh K., 1978. Optimum Land Use Pattern and Resource Allocation in a Growing Economy. Indian Journal of Agricultural Economics 33(1): 44-58.

Snapp S. S., Mafongoya P.L., and Waddington S., 1998. Organic Matter Technologies for Integrated Nutrient Management in Smallholder Cropping Systems of Southern Africa. Agriculture, Ecosystems & Environment 71(1-3): 185-200.

Snijders P. J. M., Orodho A.B., and Wouters A. P., 1992. Effect of Manure Application Methods on Yield and Quality of Napier Grass. Naivasha, Kenya: Kenya Agricultural Research Institute.

Ssembalirwa E., 2008. Urban Agriculture in Kampala City, Uganda. Kampala Local Government.

Tarawali S. A, J., Keatinge D. H., Powell J. M., Hiernaux P., Lyasse O., and Sanginga N., 2004. Integrated Natural Resource Management in West African Crop-Livestock Systems. In Sustainable Crop-Livestock Production for Improved Livelihoods and Natural Resource Management in West Africa, 349-370. Ibadan, Nigeria: International Institute of Tropical Agriculture (IITA).

Wabudeya B. M., 1996. "Factors Affecting the Adoption of Zero-Grazing among Mbale District Small-Scale Diary Farmers. MSc. Thesis". Makerere University, Kampala. Unpublished.

Zake J., Tenywa J. S., and Kabi F., 2005. Enhancement of Manure Utilization in Smallholder Cattle Management Systems for Crop Production in Central Uganda. African Crop Science Conference Proceedings, Vol. 7. pp. 1067-1071

Zake J., Tenywa J. S., and Kabi F., 2010. Improvement of Manure Management for Crop Production in Central Uganda. Journal of Sustainable Agriculture 34(6): 595-617.