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Variation of Nutrient Value in Selected Composted Farm Wastes

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Abstract

Smallholder farming is promoted for its environmental friendliness, assurance of food security sovereignty and conservation of indigenous knowledge. However, in actual practice, Smallholder farmers recycle farm plant waste to improve soil fertility. By so doing, they contribute to environmental pollution, emissions, and global warming. This situation is a Smallholder farmers' challenge worldwide. One of these challenges is the inability to find cheaper sources of plant nutrients. These sources of nutrients are associated with environmental pollution, such as the release of Methane. This study focused on farm wastes (bean trash, maize trash, banana trash, cattle slurry, goat slurry, and pig slurry) commonly produced by smallholder farmers in two farming systems of Masaka and Lyantonde Districts to explore the effects of composting and surface decomposition on nutrients contained in farm wastes by specifically: estimating baseline nutrient contents in farm wastes before disposal, determining the variation of nutrients of farm wastes managed by composting and surface decomposition and the potential source of major nutrients among selected farm wastes. Through carbon analysis, Calorimetric determination of Nitrogen and Phosphorus analysis using a block digester and UV-Visible spectrometer, Carbon, Nitrogen, Potassium and Phosphorus were determined from bean trash, maize trash, banana trash, cattle slurry, goat slurry, and pig slurry. Results revealed that goat slurry, chicken waste, maize trash and pig slurry contained more and retained more P, K, C and N, respectively, as compared to other farm wastes. Significant volumes of N and P were retained in composted materials as compared to those managed by surface decomposition.

Keywords

Farm Waste, Plant Nutrients, Smallholder Farmers, Composting, Nutrient Loss, Farming Systems

1. Introduction

The increased use of inputs, such as fertilizers, explained about half of the total increase in agricultural production between 1960 and 2007 [1]. Thus nutrient supply remains key to the success of crop production. Sustainability of this, however, remains a big challenge, especially among smallholder farming communities across farming systems [2]. The cost of fertilizers is escalating every other day [3]. In this regard, most smallholder farmers do not easily afford to buy synthetic fertilizers. They require a cheaper alternative. Composted wastes reduce the need for chemical fertilizers and/or soil amendments [4]. In the long run, production remains low and thus, a huddle shifts from one economic status to another. In Uganda, the annual Agricultural Survey 2018, which was released in May 2020, revealed that 68% of the farming community is economically constrained to improve their social economic welfare. Such vulnerability is predicted to escalate [5]. Neglect of locally available cheaper sources of crop nutrients and the resort to use of expensive fertilizers collapses their pockets.

The application of high doses of chemical fertilizers increased food production while creating several environmental and health-related problems [6]. Thus governments and change agents need empirical data to inform smallholder farmers about the golden nutrient value hidden in farm waste and the management required to explore them as recommended by [7]. In the same way, [8] reported that inefficient handling and storage of manure led to poorer C and nutrient cycling. This paper contributes to the existing body of knowledge by estimating and recording baseline nutrient content in farm wastes before disposal, determining the variation of nutrients of farm wastes managed by composting and surface disposal and the potential source of major nutrients among selected farm wastes.

2. Materials and Methods

The selected farm wastes (bean trash, maize trash, banana trash, cattle slurry, goat slurry, and pig slurry) were commonly produced by smallholder farmers in the two farming systems of Masaka and Lyantonde Districts [9]. Samples were obtained from each of these farm wastes and taken to the laboratory for analysis. The four major nutrients analyzed were: Carbon (C), Nitrogen (N), Potassium (K) and Phosphorus (P), at the National Agricultural Laboratories Research Institute Kawanda.

Baseline nutrients were determined before subjecting wastes to composting/surface decomposition. Residual nutrients (nutrients that remained after composting/surface deposition were also determined. In both scenarios (determining baseline and residual nutrients the same protocols were used, thus.

2.1. Carbon Analysis

Weighed 0.2 g of sample into a porcelain crucible. Heated the sample at 105˚C for 12 hours to remove moisture. Got weight ($Wt_{105^\circ C}$). Transferred the weighed sample into maffle furnace and combusted at 550˚C for 12 hours ($Wt_{550^{\circ}C}$). Got weight at 550˚C. Carbon was calculated as weight lost between 105˚C and 550˚C.

$$\text{Carbon content}\left(g \cdot kg^{-1}\right)=\left(\frac{Wt_{105^{\circ}C}-Wt_{550^{\circ}C}}{Wt_{105^{\circ}C}}\right)\times 100$$

2.2. Calorimetric Determination of Nitrogen

Reagents

- Dissolved 34 g of Sodium salicylate, 25 g of Sodium tartrate to prepare reagent N_1. Together in 750 ml of water, added 0.12 g of Sodium nitroprusside and made up to 1 liter with distilled water.
- Dissolved 30 g of Sodium hydroxide added 10 ml of Sodium hypochlorite, mixed and added up to 1 liter with water to prepare reagent N_2.
- Prepared the Stock solution 2500 mgN/liter by dissolving 11.79 g of ammonium sulphate in 1000 ml volumetric flask. Made up to mark with distilled water.
- Reagents N_1 and N_2 were made 24 hours before use and stored in the dark.
- Standards were prepared in a clean set of 100 ml volumetric flask containing 20 ml of water, added 2.5 ml of digestion mixture:

1) Added 0, 1.0, 3.0, 2.0, 4.0, 5.0 and 6.0 ml of stock solution.
2) Standard series contained 0, 25, 50, 75, 100, 125 and 150 mgN/liter.
3) Diluted the standard series at a ratio of 1:9 v/v with distilled water.
4) The actual concentration was 0, 2.5, 5, 7.5, 10.0, and 15.0 mgN/liter.

Procedure

Diluted the entire digest, the blanks to a ratio of 1:9 r/r with distilled water to match the standards. Using a clean micropipette, obtained 0.2 ml of sample to a clearly labeled falcon tube.

Added 5 ml of N_1 Vortex. Added 5 ml of N_2 Vortex, allowed to stand for 2 hours. Measured absorbance at 650 nm.

Plotted a calibration curve and read off N sample material calculated as:

$$N\%=\frac{a\times v\times 100}{1000\times w\times al\times 1000}$$

where,

a = concentration of N in solution.

v = total volume of end of analysis procedure.

w = weight of sample.

al = aliquot of solution picked.

2.3. Potassium and Phosphorus Analysis Using a Block Digester ad UV-Visible Spectrometer

Weighed 0.2 ± 0.001 g of oven-dried (70˚C) ground sample (40.25 mm, 60 mesh) into a labeled, dry clean digestion tube. Added 5 ml of conc. Sulphuric acid, 1 tablet of copper II sulphate. Added 0.5 ml of H_2O_2 (35%). Digested in a heating block at 420˚C for 2 hours. Cooled, added up to 50 ml with distilled water. Obtain 15 ml from the above sample and fill it in the falcon tubes.

Inserted the tubes into the sampler cabin of the spectrometer. Opened the program and followed the prompts. Results were automatically displayed.

2.4. Sampling Procedure

Before sample collection, stratification of smallholder farmers based on administrative units (Districts, Sub-county, Parish and Village) was done. Samples were purposively taken from the strata (Sub-counties and villages) [10]. The purpose was to study smallholder farmers with the major farm wastes documented as the most common [9]. The population was composed of farm wastes, represented by: bean trash, maize trash, banana trash, cattle slurry, goat slurry, and pig slurry. At village level, farm wastes used for analysis were randomly selected.

All waste materials involved in this study were sampled. This increased precision and saved on the cost of setting up experiments that would not be sampled in case sampling was randomized. Thus C, N, K and P were analyzed from 48 samples of farm wastes (bean trash, maize trash, banana trash, cattle slurry, goat slurry, and pig slurry). These nutrients were purposively selected since they are major and can influence presence of other minor nutrients.

2.5. Data Collection

Based on findings from a cross-sectional survey done by [9]; we consulted production officers at each District to purposively identify smallholder farmers dealing in livestock and crops regarded as the most important sources of farm wastes with wastes of beans, bananas, maize, pig slurry, cow slurry and goat slurry). According to [9], while at each village, local leaders identified the names of all SHFs and a list was recorded. To eliminate bias and so reduce the error, the names of these farmers were written separately on a piece of paper, put in a box, shaken and 30 names were randomly selected per village. A list of SHFs to be sampled was written down. We started collecting samples of the waste. Waste samples were taken to the laboratory at Kawanda National agriculture labs for experimentation.

2.6. Data Analysis

In this study, preliminary data was analyzed in excel using descriptive statistics. Thus, frequency tables and charts were developed to provide simple summaries of the sample and related measurements. The quantitative data was then analyzed in SPSS, starting with Variation of Nitrogen, Carbon, Potassium and Phosphorus finally. Both baseline and residual nutrient contents were added separately.

Individual nutrients were labeled as $X^{(1-3)}L$ for Lyantonde District and $X^{(1-3)}M$ for Masaka District where X represented N, C, K or P. $^{(1)}$ and $^{(2)}$ represented nutrients before and after composting/surface decomposition and $^{(3)}$ represented a change in nutrient content which was given by nutrient before composting/surface decomposition minus nutrient value after composting/surface decomposition. Correlation coefficients for specific nutrient contents, methods and types of wastes were analyzed as follows:

Nitrogen

For Masaka District, the correlation coefficients for farm waste and method were 0.211, 0.601 respectively which was non-significant ($P > 0.05$ for a two tailed test). For Lyantonde, the correlation coefficients for farm waste and method were 0.630, 0.252 respectively which was non-significant ($P > 0.05$ for a two tailed test).

Carbon

For Masaka District, the correlation coefficients for farm waste and method were 0.863, 0.496 respectively which was non-significant ($P > 0.05$ for a two tailed test). For Lyantonde, the correlation coefficients for farm waste and method were 0.743, 0.194 respectively which was non-significant ($P > 0.05$ for a two tailed test).

Potassium

For Masaka District, the correlation coefficients for farm waste and method were 0.269, 0.127 respectively which was non-significant ($P > 0.05$ for a two tailed test). For Lyantonde, the correlation coefficients for farm waste and method were 0.446, 0.292 respectively which was non-significant ($P > 0.05$ for a two tailed test).

Phosphorus

For Masaka District, the correlation coefficients for farm waste and method were 0.498, 0.234 respectively which was non-significant ($P > 0.05$ for a two tailed test). For Lyantonde, the correlation coefficients for farm waste and method were 0.463, 0.144 respectively which was non-significant ($P > 0.05$ for a two tailed test).

3. Results

3.1. Aggregated Means of Nitrogen (in ppm) before and after Composting/Surface Decomposition in ppm

In Lyantonde District, Chicken waste contained less N (97105 ppm) compared to the same waste in Masaka District which contained 98242 ppm of N. Chicken waste in Masaka District also contained the highest content of N. Maize waste in Lyantonde and Masaka Districts contained the least amount of N 36009.76 ppm and 29692.14 ppm respectively (Table 1).

For Lyantonde District:

The regression equation for N before composting/surface decomposition is:

$$
\begin{aligned}
&\text{N before composting/surface decomposition} \\
&= \text{Constant} + \text{Method} + \text{N}^{(2)}\text{L} + \text{Waste} + \text{N}^{(3)}\text{L} \\
&= 5.457\text{E}{-}012 - 2.466\text{E}{-}012 + 1.000 - 1.427\text{E}{-}01 + 1.000
\end{aligned}
$$

Table 1. Nitrogen variation.

Method	Waste	Lyantonde (Mixed Farming System)			Masaka (Arable Farming System)		
		$N^{(1)}$	$N^{(2)}$	$N^{(3)}$	$N^{(1)}$	$N^{(2)}$	$N^{(3)}$
Composting	Beans	68274.27	58070.38	10203.89	65218.36	74739.45	−9521.1
Surface decomposition	Beans	68274.27	52743.27	15,531	65218.36	66806.16	−1587.81
Composting	Bananas	41612.46	47162.59	−5550.13	36464.11	46896.94	−10432.8
Surface decomposition	Bananas	41612.46	42107.28	−494.82	36464.11	37966.17	−1502.07
Composting	Maize	36009.76	35052.24	957.52	29692.14	32675.86	−2983.73
Surface decomposition	Maize	36009.76	30190.83	5818.93	29692.14	29442.78	249.355
Composting	Cow dung	0	0	0	90805.26	105169.1	−14363.8
Surface decomposition	Cow dung	0	0	0	90805.26	96302.55	−5497.29
Composting	Goat slurry	77881.03	56959.9	20921.13	0	0	0
Surface decomposition	Goat slurry	77881.03	53506.09	24374.94	0	0	0
Composting	Chicken waste	97105.2	88160.77	8944.425	98242.37	100260.4	−2018.03
Surface decomposition	Chicken waste	97105.2	82177.78	14927.42	98242.37	92474.29	5768.08
Composting	Pig slurry	63208.5	39095.67	24112.83	37153.25	49218.13	−12064.9
Surface decomposition	Pig slurry	66541.25	37790.86	28750.39	37153.25	40879.8	−3726.56

(1), (2) Nitrogen before and after composting/surface decomposition respectively; (3) Difference in Nitrogen before and after composting/surface decomposition.

The regression equation for N after composting is:

$$\begin{aligned} &\text{N after composting/surface decomposition} \\ &= \text{Constant} + \text{N}^{(1)} + \text{Method} + \text{Waste} + \text{N}^{(1)}\text{-N}^{(3)} \\ &= -1.455\text{E}-011 + 1.000 + 4.020\text{E}-012 + 1.246\text{E}-012 - 1.000 \end{aligned}$$

The regression equation for Waste is:

$$\begin{aligned} \text{Waste} &= \text{Constant} + \text{N}^{(1)} + \text{Method} + \left(\text{N}^{(1)}\text{-N}^{(3)}\right)\text{M} \\ &= 5.558 - 1.477\text{E}-005 - 0.101 \end{aligned}$$

To compare Nitrogen content under composting and surface decomposition in both Districts, we also run a regression analysis and we see:

The regression equation for Surface decomposition:

$$\begin{aligned} \text{Surface decomposition} &= \text{Constant} + \text{waste} + \text{composting} \\ &= -1077.228 + 40.583 + 0.963 \end{aligned}$$

The regression equation for composting:

$$\begin{aligned} &= \text{Constant} + \text{waste} + \text{composting} \\ &= 1657.992 - 0.36.238 + 1.026 \end{aligned}$$

Testing the hypothesis: $\text{Ho}: \mu\text{NL}_{cb} = \mu\text{NL}_{ca} = 0$. Where, N_{cb} = Nutrient content (N in Lyantonde) before (b), (c).

$\text{Ha}: \mu\text{NL}_{cb} \neq \mu\text{NL}_{ca} \neq 0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to the method of waste management, type of waste and Nutrient content in the waste. For Method of waste management P = 0.813, P > 0.05 while for type of waste, P = 0.722, P > 0.05. This is enough evidence to fail to reject the null hypothesis.

For Masaka District:

The regression equation for N before composting is:

$$\begin{aligned}&\text{N before composting/surface decomposition}\\&=\text{Constant}+\text{N}^{(3)}\text{M}+\text{Waste}+\text{N}^{(2)}\text{M}+\text{Method}\\&=5.856\text{E}-012+1.000+2.258\text{E}-013+1.000+2.258\text{E}-013\end{aligned}$$

The regression equation for N after composting is:

$$\begin{aligned}&\text{N after composting/surface decomposition}\\&=\text{Constant}+\text{N}^{(1)}\text{M}+\text{Method}+\text{Waste}\\&=7515.889+1.022+2690.954+333.845\end{aligned}$$

The regression equation for Waste is:

$$\begin{aligned}\text{Waste}&=\text{Constant}+\text{Method}+\text{N}^{(1)}\text{M}+\text{N}^{(3)}\text{M}\\&=7.865-0.026+5.954\text{E}-0064+0.000\end{aligned}$$

To compare Nitrogen content under composting and surface decomposition in both Districts, we also run a regression analysis and we see:

The regression equation for Method:

$$\begin{aligned}\text{Nitrogen}&=\text{Constant}+\text{N}^{(3)}\text{L}+\text{N}^{(2)}\text{L}+\text{Waste}\\&=0.540+1.268\text{E}-005-3.510\text{E}-006-0.002\end{aligned}$$

Testing the hypothesis: $\text{Ho}:\mu\text{NM}_{cb}=\mu\text{NM}_{ca}=0$. Where, N_{cb} = Nutrient content (N in Masaka) before (b), (c).

$\text{Ha}:\mu\text{NM}_{cb}\neq\mu\text{NM}_{ca}\neq0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to Method of waste management, type of waste and Nutrient content in the waste. For Method of waste management P = 0.813, P > 0.05 while for type of waste, P = 0.722, P > 0.05. This is enough evidence to fail to reject the null hypothesis.

Testing the hypothesis: $\text{Ho}:\mu\text{CPN}_{b}=\mu\text{SDN}_{a}=0$. Where, CPN_{cb} = Composted N. SDN = Surface Decomposed Nitrogen, b = before, a = after

$\text{Ha}:\mu\text{CPN}_{b}\neq\mu\text{SDN}_{a}\neq0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to Method of waste management, and Nutrient content in the waste. For composting P = 0.553, P > 0.05; Surface decomposition P = 0.520. P > 0.05. This is enough evidence to fail to reject the null hypothesis.

3.2. Aggregated Means of Carbon (in ppm) before and after Composting/Surface Decomposition in ppm

Maize waste in Maska District contained 830982.2 of C. This C content was higher than C in other wastes from both farming systems. In Lyantonde District, C contained in Maize waste was 795229.9 ppm

Chicken waste contained the lowest C (531907.1 ppm) in Lyantonde compared to (617728.3 ppm) of C in Masaka District. In Masaka District, Pig slurry contained the lowest C content (605328.7 ppm) (Table 2).

In Lyantonde District, Banana waste contained more C (859587.1 ppm) compared to the same waste in Masaka District which contained 836127.7 ppm of C. Chicken waste in Lyantonde District also contained the lowest content of C (531907.1) while Pig slurry in Masaka Districts contained the least amount of C 605328.7 ppm).

For Lyantonde District:

The regression equation for C before composting/surface decomposition is:

$$\begin{aligned}&\text{C before composting/surface decomposition}\\&=\text{Constant}+\text{C}^{(2)}+\text{C}^{(3)}+\text{Method}+\text{Waste}\\&=0.896+1.000+1.000-0.298-0.090\end{aligned}$$

The regression equation for C after composting is similar to that of C before composting thus

$$\begin{aligned}&\text{C after composting/surface decomposition}\\&=\text{Constant}+\text{C}^{(2)}+\text{Method}+\text{Waste}+\text{C}^{(3)}\\&=0.896+1.000+1.000-0.298-0.090\end{aligned}$$

Table 2. Carbon variation.

	Lyantonde (Mixed Farming System)			Masaka (Arable Farming System)		
Waste	$C^{(1)}L$	$C^{(2)}L$	$C^{(3)}L$	$C^{(1)}M$	$C^{(2)}M$	$C^{(3)}M$
Beans	786042.8	626084.4	159958.4	776608.1	918884	−142276
Beans	786042.8	624396.9	161645.9	776608.1	872439.3	−95831.2
Bananas	859587.1	588174.4	271412.7	836127.7	690746.9	145380.8
Bananas	859587.1	534150.8	325436.3	836127.7	825611.2	10516.5
Maize	795229.9	812684.2	−17454.4	830982.2	917482.4	−86500.2
Maize	795229.9	805630.9	−10401.1	830982.2	891521.4	−60539.2
Cow dung	0	0	0	662448.1	607150.3	55297.75
Cow dung	0	0	0	662448.1	541920.9	120527.2
Goat slurry	554289.1	552049.7	2239.35	0	0	0
Goat slurry	554289.1	589199.9	−34910.9	0	0	0
Chicken waste	531907.1	345569.2	186337.9	617728.3	442533.6	175194.7
Chicken waste	531907.1	438705.6	93201.5	617728.3	401765.3	215,963
Pig slurry	63208.95	440676.6	−377468	605328.7	526643.4	78685.25
Pig slurry	63208.95	631508.1	−568299	605328.7	241089.4	364239.3
Carbon totals	7180530	6988831	191699	8658446	7877788	780657.9

(1) and (2) Carbon before and after composting/surface decomposition respectively; (3) Difference in Carbon before and after composting/surface decomposition.

The regression equation for Waste is:

$$\text{Waste} = \text{Constant} + C^{(2)} + C^{(3)} + \text{Method}$$
$$= 9.821 - 4.520\text{E}{-006} - 1.228\text{E}{-005} + 0.181$$

The regression equation for Method is:

$$\text{Method} = \text{Constant} + C^{(2)} + \text{Waste} + C^{(3)}$$
$$= 0.367 + 3.261\text{E}{-007} + 0.006 - 1.911\text{E}{-007}$$

Testing the hypothesis: $\text{Ho}: \mu\text{CL}_{cb} = \mu\text{CL}_{ca} = 0$. Where, C_{cb} = Carbon content (C in Lyantonde) before (b), (c).

$\text{Ha}: \mu\text{CL}_{cb} \neq \mu\text{CL}_{ca} \neq 0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to Method of waste management, type of waste and Carbon content in the waste. For Method of waste management P = 0.939, P > 0.05; C content, P = 1.000 P > 0.05 and Type of waste, P = 0.920 > 0.05. This is enough evidence to fail to reject the null hypothesis. Type of waste, P = 0.920 > 0.05.

For Masaka District:

The regression equation for C before composting/surface decomposition is:

$$\begin{aligned} &\text{N before composting/surface decomposition} \\ &= \text{Constant} + \text{Method} + \text{CdiffMsk} + \text{CAfterMsk} + \text{Waste} \\ &= -0.511 + 0.037 + 1.000 + 1.000 - 0.044 \end{aligned}$$

The regression equation for C after composting is:

$$\begin{aligned} &\text{N after composting/surface decomposition} \\ &= \text{Constant} + \text{CBeforeMsk} + \text{CdiffMsk} + \text{Method} + \text{Waste} \\ &= 0.511 + 1.000 - 1.000 + 0.037 + 0.044 \end{aligned}$$

The regression equation for Waste is:

$$\text{Waste} = \text{Constant} + \text{CBeforeMsk} + \text{CdiffMsk} + \text{Method}$$
$$= 11.869 - 7.436\text{E}{-006} + 1.439\text{E}{-005} - 1.728$$

The regression equation for Method is:

$$\text{Method} = \text{Constant} + \text{Waste} + \text{CBeforeMsk} + \text{CdiffMsk}$$
$$= 1.701 - 0.077 + 2.130\text{E}{-006} - 1.089\text{E}{-006}$$

To compare Carbon content under composting and surface decomposition in both Districts, we also run a regression analysis and we see:

The regression equation for Composting:

$$\text{Composting} = \text{Constant} + \text{Surface decomposition} + \text{waste}$$
$$= 36671.721 + 0.947 - 370.025$$

The regression equation for Surface decomposition:

$$\text{Composting} = \text{Constant} + \text{Composting} + \text{waste}$$
$$= 37092.680 + 0.962 - 1308.426$$

Testing the hypothesis: $\text{Ho}: \mu\text{CM}_{cb} = \mu\text{CM}_{ca} = 0$. Where, C_{cb} = C content in Masaka before (b), after (a).

$\text{Ha}: \mu\text{NM}_{cb} \neq \mu\text{NM}_{ca} \neq 0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to Method of waste management, type of waste and Nutrient content in the waste. For Method of waste management P = 0.397, P > 0.05; this is enough evidence to fail to reject the null hypothesis. Type of waste, P = 0.003, P < 0.05. This is enough evidence to reject the null hypothesis.

Testing the hypothesis: $\text{Ho}: \mu\text{CCP} = \mu\text{CSD} = 0$. Where, CP = Composting SD = Surface decomposition C = Carbon content.

$$\text{Ha}: \mu\text{CCP} \neq \mu\text{CSD} \neq 0$$

Carbon content P = 0.000, P < 0.05. This is enough evidence to reject the null hypothesis.

3.3. Aggregated Means of Potassium (in ppm) before and after Composting/Surface Decomposition in ppm

From Table 3, Lyantonde District, K was highest in Goat slurry up to a tune of 5254 ppm. In Masaka District, K was highest in Chicken waste (4659 ppm). Lowest K was recorded in Maize waste (1321 ppm) from Lyantonde District. In Maska District, lowest contents of K were recorded in Beans (2351 ppm), (Table 3).

For Lyantonde District:

Table 3. Potassium variation.

Method	Waste	Lyantonde (Mixed Farming System)			Masaka (Arable Farming System)		
		K^{Before} (ppm)	K^{After} (ppm)	Difference $^{(ppm)}$	K^{Before} (ppm)	K^{After} (ppm)	Difference $^{(ppm)}$
Composting	Beans	3284.65	2349.193	935.457	2850.739	5855.898	−3005.16
Surface decomposition	Beans	3284.65	2317.948	966.702	2850.739	2669.97	180.769
Composting	Bananas	3572.484	4232.623	−660.139	5564.683	5240.593	324.09
Surface decomposition	Bananas	3572.484	4106.688	−534.204	5564.683	5838.595	−273.912
Composting	Maize	4775.533	3593.985	1181.548	3044.662	2575.268	469.3935
Surface decomposition	Maize	4775.533	2527.083	2248.45	3044.662	2589.535	455.1265
Composting	Cow dung	0	0	0	2374.721	2602.593	−227.873
Surface deposition	Cow dung	0	0	0	2374.721	2402.698	−27.9775
Composting	Goat slurry	3722.551	3013.348	709.2025	0	0	0
Surface decomposition	Goat slurry	3722.551	2057.275	1665.276	0	0	0
Composting	Chicken waste	3961.333	3029.085	932.248	3636.349	4659.215	−1022.87
Surface decomposition	Chicken waste	3961.333	5511.21	−1549.88	3636.349	3636.363	−0.014
Composting	Pig slurry	1870.094	1733.348	136.7455	2907.976	2511.583	396.393
Surface decomposition	Pig slurry	1870.094	1632.048	238.0455	2907.976	2798.045	109.931

(1) and (2) Potassium before and after composting/surface decomposition respectively; (3) Difference in Potassium before and after composting/surface decomposition.

The regression equation for K before composting/surface decomposition is:
K before composting/surface decomposition:

$$\begin{aligned} &\text{K before composting/surface decomposition} \\ &= \text{Constant} + \text{K}^{(2)}\text{L} + \text{Method} + \text{Waste} + \text{K}^{(3)}\text{L} \\ &= -0.001 + 1.000 + 0.000 + 8.177\text{E}-005 + 1.000 \end{aligned}$$

The regression equation for K after composting is:

$$\begin{aligned} &\text{K after composting/surface decomposition} \\ &= \text{Constant} + \text{K}^{(1)}\text{L} + \text{Method} + \text{Waste} + \text{K}^{(3)}\text{L} \\ &= 0.001 + 1.000 + 0.000 - 8.177\text{E}-005 - 1.000 \end{aligned}$$

The regression equation for Waste is:

$$\begin{aligned} \text{Waste} &= \text{Constant} + \text{K}^{(3)}\text{L} + \text{Method} + \text{K}^{(2)}\text{L} \\ &= 8.710 - 0.001 + 0.987 + 0.000 \end{aligned}$$

The regression equation for Method is:

$$\begin{aligned} \text{Method} &= \text{Constant} + \text{Waste} + \text{K}^{(2)}\text{L} + \text{K}^{(3)}\text{L} \\ &= 0.350 + 0.016 + 9.826\text{E}-006 + 8.427\text{E}-006 \end{aligned}$$

Testing the hypothesis: $\text{Ho}: \mu\text{KL}_{cb} = \mu\text{KL}_{ca} = 0$. Where, K_{cb} = Potassium content (K in Lyantonde) before (b), (c).

$\text{Ha}: \mu\text{CL}_{cb} \neq \mu\text{CL}_{ca} \neq 0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to Method of waste management, type of waste and Potassium content in the waste. For Method of waste management P = 0.982, P > 0.05; Type of waste, P = 0.852 > 0.05; this is enough evidence to fail to reject the null hypothesis. K content, P = 0.000 P < 0.05. This is not enough evidence to fail to reject the null hypothesis.

For Masaka District:

The regression equation for K before and after composting/surface decomposition is:

$$\begin{aligned} &\text{K before composting/surface decomposition} \\ &= \text{Constant} + \text{Method} + \text{Waste} + \text{K}^{(3)}\text{M} + \text{K}^{(2)}\text{M} \\ &= 0.000 - 0.001 + 8.575\text{E}-005 + 1.000 + 1.000 \end{aligned}$$

$$\begin{aligned} &\text{K after composting/surface decomposition} \\ &= \text{Constant} + \text{K}^{(1)}\text{M} + \text{Method} + \text{K}^{(3)}\text{M} + \text{Waste} \\ &= 0.000 + 1.000 + 0.001 - 1.000 - 8.575\text{E}-005 \end{aligned}$$

The regression equation for Waste is:

$$\begin{aligned} \text{Waste} &= \text{Constant} + \text{K}^{(2)}\text{M} + \text{Method} + \text{K}^{(3)}\text{M} \\ &= 10.001 - 0.001 + 0.282 - 0.001 \end{aligned}$$

The regression equation for Method is:

$$\begin{aligned} \text{Method} &= \text{Constant} + \text{Waste} + \text{K}^{(1)}\text{M} + \text{K}^{(3)}\text{M} \\ &= 0.478 + 0.005 + 4.957\text{E}-006 + 0.000 \end{aligned}$$

To compare Potassium content under composting and surface decomposition in both Districts, we also run a regression analysis and we see:

The regression equation for composting Method is:

$$= \text{Constant} + \text{Surface decomposition} + \text{Waste}$$
$$= 1030.432 + 0.834 - 30.393$$

The regression equation for Surface decomposition Method is:

$$= \text{Constant} + \text{Composting} + \text{Waste}$$
$$= -4.459 + 0.881 + 16.468$$

Testing the hypothesis: $\text{Ho}: \mu\text{CM}_{cb} = \mu\text{CM}_{ca} = 0$. Where, C_{cb} = C content in Masaka before (b), after (a).

$\text{Ha}: \mu\text{NM}_{cb} \neq \mu\text{NM}_{ca} \neq 0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to Method of waste management, type of waste and Nutrient content in the waste. For Method of waste management P = 0.817, P > 0.05; Type of waste, P = 0.508, P > 0.05. This is enough evidence to fail to reject the null hypothesis. Potassium content P = 0.00 < 0.05. This is enough evidence to reject the null hypothesis

Testing the hypothesis: $\text{Ho}: \mu\text{KCP} = \mu\text{KSD} = 0$. Where, CP = Composting SD = Surface decomposition K = Potassium content.

$$\text{Ha}: \mu\text{KCP} \neq \mu\text{KSD} \neq 0$$

Composting P = 0.873, P < 0.05; Surface decomposition P = 0.863 P > 0.05. This is enough evidence to reject the null hypothesis.

3.4. Aggregated Means of Phosphorus (in ppm) before and after Composting/Surface Decomposition in ppm

In Lyantonde District, P was highest in Goat slurry up to a tune of 4511.495 ppm. In Masaka District, P was highest in Chicken waste (5034.457 ppm). The lowest P was recorded in Banana waste (1602.391 ppm) from Lyantonde District. In Maska District, the lowerst contents of K were recorded in Cow dung (2804.739 ppm) (Table 4).

For Lyantonde District:

The regression equation for P before composting/surface decomposition is:

$$\text{P before composting/surface decomposition}$$
$$= \text{Constant} + \text{Method} + \text{P}^{(2)}\text{L} + \text{Waste} + \text{P}^{(3)}\text{L}$$
$$= -0.001 + 0.001 + 1.000 + 9.511\text{E}-006 + 1.000$$

The regression equation for P after composting is similar to that of C before composting thus.

P after composting/surface decomposition:

$$\text{P after composting/surface decomposition}$$
$$= \text{Constant} + \text{Method} + \text{P}^{(2)}\text{L} + \text{Waste} + \text{P}^{(3)}\text{L}$$
$$= -0.001 + 0.001 + 1.000 + 9.511\text{E}-006 + 1.000$$

Table 4. Variation of phosphorus.

Method	Waste	Lyantonde (Mixed Farming System)			Masaka (Arable Farming System)		
		P^{Before} (ppm)	P^{After} (ppm)	Difference (ppm)	P^{Before} (ppm)	P^{After} (ppm)	Difference (ppm)
Composting	Beans	2052.115	1705.705	346.41	3551.161	3863.405	−312.244
Surface decomposition	Beans	2052.115	1535.305	516.81	3551.161	5219.308	−1668.15
Composting	Bananas	1602.391	508.06	1094.331	3976.165	4488.528	−512.364
Surface decomposition	Bananas	1602.391	518.3075	1084.083	3976.165	3122.34	853.8245
Composting	Maize	2116.325	3233.185	−1116.86	3514.681	1939.87	1574.811
Surface decomposition	Maize	2116.325	2972.775	−856.45	3514.681	2248.22	1266.461
Composting	Cow dung	0	0	0	2804.739	2786.038	18.701
Surface deposition	Cow dung	0	0	0	2804.739	2224.53	580.209
Composting	Goat slurry	4511.495	3295.843	1215.652	0	0	0
Surface decomposition	Goat slurry	4511.495	5713.64	−1202.15	0	0	0
Composting	Chicken waste	3720.746	3214.425	506.321	3260.889	3857.285	−596.396
Surface decomposition	Chicken waste	3720.746	2792.353	928.393	3260.889	3465.31	−204.421
Composting	Pig slurry	2676.882	2920.885	−244.004	5034.457	8440.18	−3405.72
Surface decomposition	Pig slurry	2676.882	1837.303	839.5785	5034.457	7136.19	−2101.73

(1) and (2) Phosphorus before and after composting/surface decomposition respectively; (3) Difference in Phosphorus before and after composting/surface decomposition.

The regression equation for Waste is:

$$\text{Waste} = \text{Constant} + P^{(1)}L + \text{Method} + P^{(3)}L$$
$$= 3.884 + 0.001 + 0.988 + 0.000$$

The regression equation for Method is:

$$\text{Method} = \text{Constant} + \text{Waste} + P^{(3)}L + P^{(1)}L$$
$$= 0.421 + 0.019 - 2.410E{-}005 - 2.441E{-}005$$

Testing the hypothesis: $Ho: \mu PL_{cb} = \mu PL_{ca} = 0$. Where, P_{cb} = Phosphorus content (P in Lyantonde) before (b), (c).

$Ha: \mu PL_{cb} \neq \mu PL_{ca} \neq 0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to Method of waste management, type of waste and Carbon content in the waste. For Method of waste management P = 0.144, P > 0.05; P content, P = 1.000 P > 0.05 and Type of waste, P = 0.463 > 0.05. This is enough evidence to fail to reject the null hypothesis.

For Masaka District:

The regression equation for P before composting/surface decomposition is:

$$\text{P before composting/surface decomposition}$$
$$= \text{Constant} + P^{(3)}M + \text{Method} + \text{Waste} + P^{(2)}M$$
$$= 0.003 + 1.000 + 0.001 + 0.000 + 1.000$$

The regression equation for P after composting is:

$$\text{P after composting/surface decomposition} = \text{Constant} + \text{P}^{(1)}\text{M} + \text{Method} + \text{Waste} + \text{P}^{(3)}\text{M} = -0.003 + 1.000 - 0.001 + 0.000 - 1.000$$

The regression equation for Waste is:

$$\text{Waste} = \text{Constant} + \text{P}^{(2)}\text{M} + \text{Method} + \text{P}^{(3)}\text{M} = 8.257 - 0.001 + 1.461 - 0.002$$

The regression equation for Method is:

$$\text{Method} = \text{Constant} + \text{Waste} + \text{P}^{(1)}\text{M} + \text{P}^{(3)}\text{M} = 0.209 + 0.028 + 3.448\text{E}-005 + 9.409\text{E}-005$$

To compare Carbon content under composting and surface decomposition in both Districts, we also run a regression analysis and we see:

The regression equation for Composting

$$\text{Composting} = \text{Constant} + \text{Waste} + \text{Surface decomposition} = 1959.237 + 89.695 + 0.299$$

The regression equation for Surface decomposition.

Composting = Constant + Composting + Waste.

Testing the hypothesis: $\text{Ho}: \mu\text{PM}_{cb} = \mu\text{PM}_{ca} = 0$. Where, P_{cb} = P content in Masaka before (b), after (a).

$\text{Ha}: \mu\text{PM}_{cb} \neq \mu\text{PM}_{ca} \neq 0$. Data were analyzed at 0.05 significance level. At this level of significance, we were 95% confident that any difference noticed was due to Method of waste management, type of waste and Nutrient content in the waste. For Method of waste management P = 0.393, P > 0.05; Type of waste P = 0.899, P > 0.05. This is enough evidence to fail to reject the null hypothesis.

Testing the hypothesis: $\text{Ho}: \mu\text{PCP} = \mu\text{PSD} = 0$. Where, CP = Composting SD = Surface decomposition K = Potassium content.

$\text{Ha}: \mu\text{PCP} \neq \mu\text{PSD} \neq 0$

Composting P = 0.720, P > 0.05; Surface decomposition P = 0.021 P > 0.05. This is enough evidence to reject the null hypothesis

4. Discussion

On average, fewer nutrients were lost in farm wastes collected from Lyantonde District (−262202 ppm), as shown using equation one compared to the average nutrients lost in farm wastes from Masaka District (−39630.2 ppm) shown using Equation (2).

$$\text{Nutrients lost in Lyantonde District} = \sum\left(\text{lN}^{(1)} + \text{lP}^{(1)} + \text{lC}^{(1)} + \text{lK}^{(1)}\right) - \sum\left(\text{lN}^{(2)} + \text{lP}^{(2)} + \text{lC}^{(2)} + \text{lK}^{(2)}\right) \quad (1)$$

$$\text{Nutrients lost in Masaka District} = \sum\left(\text{mN}^{(1)} + \text{mP}^{(1)} + \text{mC}^{(1)} + \text{mK}^{(1)}\right) - \sum\left(\text{mN}^{(2)} + \text{mP}^{(2)} + \text{mC}^{(2)} + \text{mK}^{(2)}\right) \quad (2)$$

Thus,

$$\begin{aligned}
&\text{Nutrients lost in Lyantonde District} \\
&= (-641765.4 + 33359.91 + 7180530 + 42373.29) \\
\text{1)}\quad &\quad -(623017.7 + 30247.79 + 6988830.7 - 6269.453) \\
&= 7898029 - 7635827 \\
&= 262202 \text{ ppm}
\end{aligned}$$

$$\begin{aligned}
&\text{Nutrients lost in Masaka District} \\
&= (-18747.8 + 44284.18 + 8658446 + 40758.26) \\
\text{2)}\quad &\quad -(715150.9 + 48791.2 + 7877788 + 43380.36) \\
&= 8724741 - 8685110 \\
&= -39631 \text{ ppm}
\end{aligned}$$

where: $lN^{(1)}$, $lP^{(1)}$, $lC^{(1)}$ and $lK^{(1)}$ are Nitrogen, Phosphorous, Carbon and Potassium respectively in Lyantonde District.

While $mN^{(1)}$, $mP^{(1)}$, $mC^{(1)}$ and $mK^{(1)}$ are Nitrogen, Phosphorous, Carbon and Potassium respectively in Masaka District; $^{(1)}$ and $^{(2)}$ represent study nutrients before and after composting/surface decomposition respectively.

Social and economic factors are responsible for the variation of livestock waste among the two farming systems. For example, goat slurry was not a common waste in Masaka, the reason being the browsing nature of goats yet tethering was the common grazing system. Under such a grazing system, goats often stray and destroy crops which raise conflicts among farmers. As a result, goats were not so popular in this arable farming system. On the other hand, cow dung was not common in Lyantonde despite the fact that it is a mixed farming system. This is justified by the fact that most SHFs in Lyantonde could not afford to rear cows, given the high cost of livestock alongside the lack of grazing land. Most grazing land is owned by rich commercial farmers, leaving very small patches of marginalized nature to the SHFs. As reported by [7] and [11], in smallholder agriculture, adaptive capacity—or the ability to identify and implement effective actions in response to changing circumstances is limited by barriers to the adoption of improved technologies and practices. For example, lack of access to credit makes smallholder farmers unable to invest in expensive livestock such as cattle even when their rich neighbors have them like it is in Lyantonde District. In the long run cow dung wastes were not popular in Lyantonde as opposed to Masaka District, where many smallholder farmers generated cattle wastes.

The difference in nutrients before and after the experiment presupposes that the lost nutrients such as C and N could have accounted for the generation of GHG emissions. The observation of fewer nutrients after composting/surface decomposition compared to the baseline nutrients can be explained on two accounts: the first is the loss of carbon in a gaseous form during the decomposition process. It was either lost as gaseous carbon or combined with oxygen to form carbon dioxide which is a greenhouse gas lost to the atmosphere. Additionally, GHG emissions such as CO_2 and CH_4 caused by livestock wastes are a serious problem to the environment [12]. The bigger proportion of NH_3, CO_2, and CH_4 produced the smaller the nutrients left for crop production [2]. The second account is the loss of carbon through micro-organisms that feed on organic matter and convert it into their body cells/tissues.

The indicated difference in nutrients among farm wastes was also explained by [2] when he reported that nutrient values varied as a result of variation in storage conditions (aeration, storage period, temperature), manure characteristics (degradability, moisture content), that strongly affect the rate of organic matter degradation and carbon loss [2]. Similarly, variation of nutrients in these two farming systems showed the same trend.

Leaching could also have had an effect on the variation of the nutrients during composting/surface decomposition.

Agronomic practices through which these wastes were generated also contributed to the nutrient value differences depicted. [4] reported that a low proportion of households in Masaka engaged in composting, which could tremendously impact nutrient availability. Low engagement in household composting could be partly attributed to a lack of knowledge of the technical aspects of composting like equipment to use and entire composting process. Another likely explanation for the low engagement in household composting could be due the negative attitudes toward composting. Negative perceptions have been found to be a predictor for composting at the household level. All these indicate the rare use of organic sources of nutrients hence a likelihood of poor soils. The poor farm practices reported by [13] justify the variation of nutrient contents of crops grown by smallholder farmers. [14] reported that acidifying conditions in soils were accelerated by erosion and management practices involved.

Variation in soil nutrients where these crop wastes were produced also leads to the variety of nutrients in the crop waste. Lyantonde and Masaka Districts are located differently. For example, according to [15], Lyantonde District is located in pastoral and some annual crop system areas. The soils in this farming system are mainly Vertisols, Cambisols, Luvisols and Plinthosols. Masaka District is located in the banana coffee farming system. The soils in this farming system are Nitisols and Ferralsols. Thus different soil types can account for the variety of nutrients available in both crop wastes and livestock feeds.

The waste management practice through which the wastes were managed had an effect on the variation of nutrients in the waste. As reported by [9], SHFs' waste management practices in Lyantonde and Masaka majorly included Surface deposition, Burning, Composting, Burry, Removal, and Recycling. Each of these methods has its own dynamics, such as efficacy that vary from one method to another. As depicted in Sections 2.4 to 3.1, on average more nutrients were lost during surface decomposition compared to composting.

The type of soil amendment used by SHFs also affected the nutrient content before and after composting/surface decomposition. In particular, characteristics of soil amendments used influenced the values of crops/pastures harvested [16]. Soil organic inputs commonly used by smallholder farmers have high potential of increasing soil pH through chelation of Al^{3+} and Fe^{3+} [17]. Thus, the type of nutrient source, nutrient content in the soil, nutrient content in the crop/animal and these wastes relate to one another. [18] reported that the differences in yields and soil properties are explained by the nature of the organic waste products used. The use of modern inputs impacted the output values in terms of nutrient contents availability within crops/pastures that were later reflected in the farm wastes as baseline nutrients.

5. Conclusion

Nutrient variation across farming systems is a general phenomenon that farmers and all the stakeholders need to take care of to guarantee sustainable crop production. Adherence to both good farming practices and good waste management practices can save SHFs from being more vulnerable when searching for soil amendments beyond their farms. After all, the external inputs pose a financial burden to the incomes of these SHFs while the environment is also not spared. The environment is polluted as a result of GHG emissions from poorly managed nutrients such as Carbon dioxide, Nitrous oxide and Methane among others. A combination of these two burdens gets worse when it turns into climate change. At such a stage, all farm components (on-farm and beyond) get paralyzed and food production to feed the world crumbles.

6. Recommendations

The paralyzed agro-ecosystems due to both poor farming practices and waste management practices among SHFs can be rejuvenated through a series of multi-stakeholder involvement, particularly in the field of research, training and extension, formulating policies that promote and support on-farm nutrient recycling from farm waste and incentive-based waste management practices will also address farmers needs that prompt them to look for what is believed to be "cheap" but deadly soil amendments. This agrees well with [19], who recommended that to improve the agricultural productivity of Ugandan soils, farmers need to utilize the organic fraction of solid waste as fertilizers through composting. In particular, based on the variation of nutrients given by this study, the researcher strongly recommends an investigation into GHG emissions due to waste management practices among SHFs in these two farming systems.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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