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## RESEARCH ARTICLE

# EFFECT OF SHEA WASTE SLURRY ON SOIL PHYSICAL PROPERTIES IN PERI-URBAN TAMALE, NORTHERN GHANA

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## ABSTRACT

The study determined the effect of Shea waste-slurry on soil physical properties in two peri-urban areas of Tamale Metropolis in Ghana. Results indicated bulk densities of 0.95 to 1.35 g/cm$^3$ and 1.27 to 1.33 g/cm$^3$ for disposal sites at Gumu and Kasalgu respectively. Higher bulk densities of 1.30 to 1.52 g/cm$^3$ for Gumu and 1.35 to 1.52 g/cm$^3$ for Kasalgu were recorded for the non-disposal sites. Gravimetric moisture content ranged from 0.08 to 0.15 g/g for disposal site and 0.10 to 0.11 g/g for non-disposal site at Gumu. Kasalgu recorded 0.07 to 0.12 g/g for the disposal site and 0.02 to 0.11 g/g for the non-disposal site. Higher volumetric moisture content of 13.4 to 15.5 % for the disposed site compared to 12.3 to 13.3 % for the non-disposal site of was recorded. Volumetric moisture at Kasalgu disposal site was 0.9 to 16.4 % and 13.4 to 15.5 % for non-disposal site. Porosity which relates directly with aeration at the root zone of crops was 49.1 to 64.2 % for the disposal site at Gumu and 42.6 to 50.9 % for the non-disposal site. Porosity at Kasalgu disposal site range from 49.8 to 51.9 % and 42.8 to 48.9 % for the non-disposal site. The study shows differences between the soil physical properties of sites where Shea waste-slurry was disposed and that of the non-disposal sites. Shea waste-slurry was therefore found to improve soil physical properties and is consequently expected to have positive effects on crop growth and yield.

**Key words:** Physical, Properties, Shea, Soil, Slurry, Waste,

## INTRODUCTION

The Shea tree (*Vitellaria paradoxa*) has gained importance as an economic crop in recent years because of the increasing demand for its butter both locally and internationally. As a rural industry, Shea butter contributes considerably to the annual income of rural communities of West Africa countries (Yidana, 2004). The Shea tree is an indigenous and exclusive asset in West and Central Africa and particularly abundant in the Northern savannah areas of Ghana (Addaquay, 2004). Shea waste-slurry is said to be the concentration of solids and the water as well as the fats that remains after the extraction of the oil from the Shea nut and it is used in so many ways; the residue serves as a potential source of fuel for domestic heating. The need to identify additional sources of feed, to expand the animal industry for protein supply in Ghana, led to research into the potential for greater use of agro-based industrial by-products, such as Shea nut cakes in the formulation of animal feeds (Fleury, 1981). Soil plays an important role in providing food for the human, as it supports and facilitate crop growth. Soil physical properties are those characteristics, processes, and reactions of a soil that are caused by physical forces that can be described by, or expressed in physical quantities or equations (Brady and Weil, 2002). Waste, especially, organic waste has some dramatic effect on soil physical properties. Application of organic waste improved soil hydrologic properties like infiltration rate and hydraulic conductivity (Diana *et al.*, 2008). While compost has led to the beneficial effects on hydrological physical properties of the soil such as pore size distribution, aggregate stability and soil water retention (Wanas, 2002). As urbanization continues to take place, management of solid and liquid waste especially Shea waste-slurry is becoming a major public health and environmental concern in urban areas of developing countries one of which includes the Tamale Metropolis in Ghana. Considerable quantities of Shea waste-slurry are disposed off on farmlands used for annual crop production such as maize and vegetables in the Tamale Metropolis. The study determined the effect of Shea waste-slurry on soil physical properties in the Peri-urban area of Tamale Metropolis of Ghana.

## MATERIALS AND METHODS

***Study area:*** The Tamale Metropolitan Area is located at the centre of the Northern Region of Ghana. The Tamale Metropolis occupies approximately 750 km$^2$ which is 13% of the total area of the Northern Region. According to the Ghana Statistical Service (2010), the projected Tamale Metropolis has a population of 414,548. The main soil bedrock materials in the Metropolis are sandstone, mudstone and shale which have weathered into different soil grades. Due to seasonal erosion, soil types emanating from this phenomenon are sand, clay and laterite ochrosols. The major crops cultivated include

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maize, rice, millet, sorghum, cowpea, groundnut, soya beans, yam and cassava.

***Materials:*** Field and laboratory materials include core samplers, stop watch, graduated beaker, graduated cylinder, infiltrometer, Global Position System (GPS), Thermometer, Distilled Water, sodium hexametaphosphate solution, oven, mechanical stirrer and electronic balance.

***Data Collection:*** Soil samples and field experiments were undertaken in April 2011 before the onset of the rains. Twelve (12) soil samples were taken from four (4) sites and three (3) plots each at a sampling depth of 0 – 30 cm. The geographical location of the sampling sites is as in Table 1. Plates 1 and 2 show the disposal and non-disposal sites of Shea waste-slurry in the study area.

**Plate 1: Soil Surface of Shea Waste-Slurry Disposal Site**

**Plate 2: Soil Surface of Shea Waste-Slurry Non-disposal Site**

***Methods***

***Gravimetric Moisture Content***

The gravimetric method as described by Gardner (1986) was used to establish initial soil water content for both sites. Wet samples were weighed, dried in an oven at 105 °C for 24 hours, and then weighed again. Gravimetric soil water content was then determined by the relation:

$$\theta_g = \frac{\text{mass of wet of soil} - \text{mass of dry soil}}{\text{mass dry soil}} \ (\text{gg}^{-1}) \qquad \text{equation 1}$$

Where $\theta_g$ is Gravimetric Moisture Content

***Bulk Density***

The dry bulk density of the soil samples was determined from soil cores collected from the field with core sampler (Klute, 1987). The cylindrical metal sampler (core sampler) with a diameter of 5 cm and a height of 5 cm was vertically driven into the soil. In order to prevent compression of the soil, another cylinder of equal diameter and height was placed directly on top of the first sampler. The sampler and its contents were then removed carefully so as to protect the natural structure and packing of the soil from being disturbed. The volume of the soil was taken to be the same as the volume of the cylinder. The cylinders were closed and taken to the laboratory for oven drying at 105 °C to constant mass. The oven dried soils were weighed and the bulk densities were calculated using the relation:

$$\rho_b = \frac{\text{mass of dry soil and core sampler } (M_2) - \text{mass of core sampler } (M_1)}{volume\ of\ soil (V)} \ (\text{g/cm}^3) \qquad \text{equation 2}$$

Where $\rho_b$ is Bulk Density

***Volumetric Moisture Content***

The Volumetric water content ($\theta_v$) was determined from the relation:

$$\theta_v = \theta g . \frac{\rho_b}{\rho_w} \qquad \text{equation 3}$$

$$\text{Where } \theta g = \frac{M_w}{M_s} \qquad \text{equation 4}$$

$$\text{Therefore } \theta_v = \theta g . \rho_b \qquad \text{equation 5}$$

(Assuming $\rho_w$= 1), $\theta g$ = gravimetric water content, $\rho_b$ = bulk density of the soil, and $\rho_w$ = the bulk density of water.

***Porosity***

Total porosity was calculated from the relation:

$$f = 1 - \frac{\rho_b}{\rho_w} \qquad \text{equation 6}$$

Where f = total porosity,

$\rho_b$ = bulk density, and

$\rho_s$ = particle density (2.65 $gcm^{-1}$).

***Particle Size Distribution***

The hydrometer method as described by Klute (1987) was used in the determination of the textural class of the soils.

***Field Infiltration Measurement***

Field infiltration was measured using a mini disc infiltrometer of 90 ml measuring cylinder. The vertical infiltration was measured in the cylinder for an hour in all the twelve (12) plots of both disposal and non-disposal sites.

## RESULTS AND DISCUSSIONS

***Effect of Shea Waste-Slurry on Soil Bulk Density***

The bulk density of the entire soil samples for disposal site at Gumu was lower than that of the samples of the non-disposal site. The bulk densities ranged from 0.95 to 1.35 g/cm$^3$ for the disposal site whilst at the non-disposal site at Gumu it ranged from 1.30 to 1.52 g/cm$^3$. It was also realized that for disposal sites at Kasalgu, bulk densities recorded were 1.27 to 1.33 g/cm$^3$ whilst at the non-disposal sites these values were somewhat higher and ranged from 1.35 to 1.52 g/cm$^3$. Agyare (2004) reported that the bulk density of soils in the Tamale area ranged from 1.15 to 1.89 g/cm$^3$ in the top soil and 1.10 to 1.93 g/cm$^3$ in the sub soil. It was however evidently clear that the bulk densities of the non-disposal sites were somewhat higher than the disposal sites thus emphasizing the effect of Shea waste-slurry on soil bulk density. These values were however within the range described by Agyare (2004). Bonsu and Asubio (2000) and Mengel and Barber (1974) reported that soils of the savanna area have low organic matter content and hence low nutrient status resulting in generally high bulk density. Since high bulk densities values were observed in the non-disposal sites and low values at the disposal sites, the effect of the Shea waste-slurry on soils of the areas is evident on the reduction of soil bulk densities and possible consequent increase in organic matter content. The soil bulk densities and sampling plots are presented in Table 2.

### *Influence of Shea Waste-Slurry on Gravimetric and Volumetric Moisture Content*

Soils taken from disposal site at Gumu retained moisture ranging from 0.08 to 0.15 g/g compared to the non-disposal site of 0.10 to 0.11 g/g. Ayeni *et al.,* (2008) indicated that, poultry manure addition to the soil up to fifty tons per hectare increased soil moisture content. This means that there is retention of more water in the soil pores at Gumu disposal site as compared to the non-disposal site. The improvement in soil gravimetric moisture content could be attributed to the presence of the Shea waste-slurry that influenced soil structure which has positive effect on water retention capacity of the soil. Compared to the trend in the sites of Gumu, Kasalgu exhibited a somewhat opposite trend and the gravimetric moisture contents are as shown in Table 2. At the disposal site of Kasalgu the entire gravimetric moisture content experienced an increase even though the difference was not significant and it ranged from 0.07 to 0.12 g/g. However, at the non-disposal site, lower gravimetric moisture content compared to the disposal site was recorded and it ranged from 0.02 to 0.11 g/g. Agbede *et al*., (2008), indicated that poultry manure improved soil physical properties by increasing moisture content with yearly application giving cumulative positive effect.

The variation in gravimetric moisture content at the study sites therefore shows the positive effect of Shea waste-slurry on soil moisture availability, with a possible significant effect on long term basis. Volumetric moisture content at the Gumu disposal study site ranged from 13.4% to 15.5% compared to 12.3% to 13.3% at the non-disposal site. This shows the effect of the Shea waste-slurry on the water holding capacity of the soil as it has improved the water content of the soil when it was deposited on it. Results of the total volumetric moisture content for disposal site at Kasalgu shows a higher level (0.9% to 16.4%) than that of the non-disposal site of 13.4% to 15.5%. According to Uson and Cook (1995), improved soil water retention was possible in compost incorporated and mulched soils. It is therefore very evident that the effect of Shea waste-slurry on the availability and water holding properties of the soils in the study sites is very high and therefore can be used as an organic residue for improving the soil water holding capacity.

### *Effect of Shea Waste-Slurry on Soil Particle Size Distribution and Porosity*

Laboratory results of the soil samples showed that out of the twelve (12) soil samples, six (6) were found to be sandy loam, four (4) were loamy sand, one (1) was sandy and one (1) was loam. Soils at the study sites of Gumu were loamy sand with sand content ranging from 76.92% to 80.92%, clay content being in the range of 4.6% to 6.6% and silt content being 12.48% to 16.48%. At Kasalgu non-disposal site, one sampling plot exhibited loamy soil characteristics with the second plot showing sandy soil characteristics and the third plot exhibiting sandy loam soil. All the three plots at Kasalgu disposal site were however found to be sandy loam. The particle sizes of the three (3) plots of the disposal sites were 62.92% to 68.12% sand, 4.6% to 14.65% clay and 22.48% to 32% silt. The soil particle size characteristics of the non-disposal plots at Kasalgu however varied greatly and these and the other plots are presented in Table 3.

Table 3 shows the trend of porosity for all the sampling plots of the study. The porosity for the disposal sites ranged from 42.60 to 50.90 % while the non-disposal sites also ranged from 49.10 to 64.20 %. According to Pagliai *et al.,* (1981), application of municipal waste was found to increase soil porosity. The reduction in the porosity of the studied soil therefore relates directly to the soil types and the effect of the Shea waste-slurry. Soil organic matter has been reported by Obi and Ebo (1995) to stabilize soil structure thereby reducing soil bulk density and increasing porosity. With the effect of the Shea waste-slurry in the reduction of the soil porosity, the rate of soil water loss as well as nutrient leaching will be reduced and this has the potential of enhancing the growth and yield of food crops.

### *Effect of Shea Waste Slurry on Soil Water Infiltration*

Figures 1 and 2 clearly show that values of infiltration rate varied widely between disposal sites and non-disposal sites except few plots and of which are classified as slow to moderate.

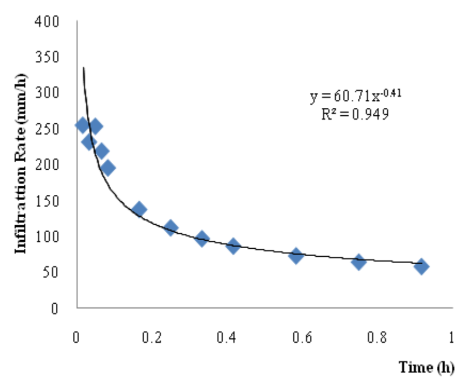


**Figure 1: Infiltration Rate of GDA**

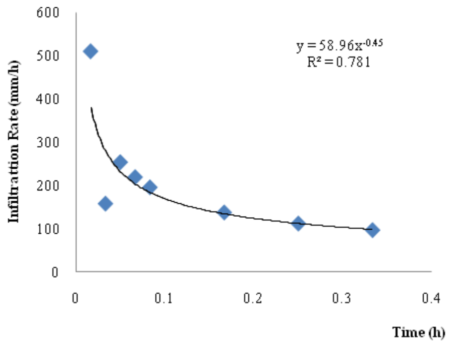


**Figure 2: Infiltration Rate of GUA**

Figure 1 displays an infiltration rate curve at Gumu disposal site plot A and it was observed that 52.97 mm/h was recorded which is classified as moderate while the infiltration rate curve of the Gumu non-disposal site plot A was higher with an infiltration value of 96.51 mm/h and so classified as moderate to rapid. With the predominant soil type being loamy sand, leaching of soil nutrients could be higher with high infiltration rates. It is therefore evident from the results that Shea waste-slurry has an effect of reducing high rates of infiltration and subsequently high level retention of soil water. Mubarak *et al*., (2009) reported that there was a decrease in water movement in sandy soils amended with organic residues.

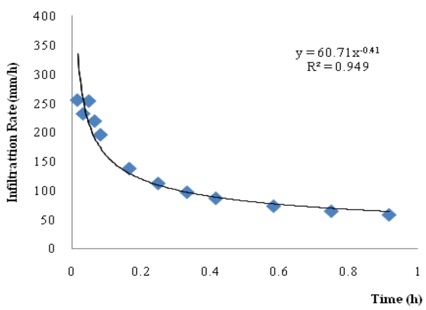


**Figure 3: Infiltration Rate of GDB**

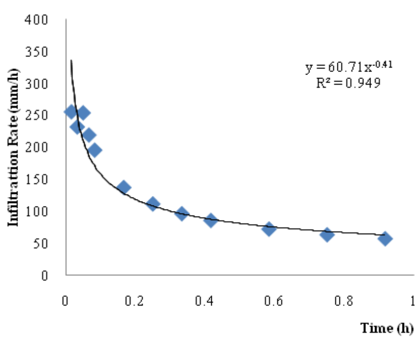


**Figure 4: Infiltration Rate of GUB**

At Gumu disposed site plot B (Figure 3) an infiltration rate of 52.97 mm/h was recorded and it is classified as moderate compared to a moderate to rapid infiltration rate of 72.59 mm/h for Gumu non-disposal site plot B as shown in Figure 4. According to Ibrahim and Gaheen (1999) the application of composts caused marked changes on soil water infiltration rate. The variation in the infiltration rates therefore shows clearly the effect of the Shea waste-slurry as soil organic material.

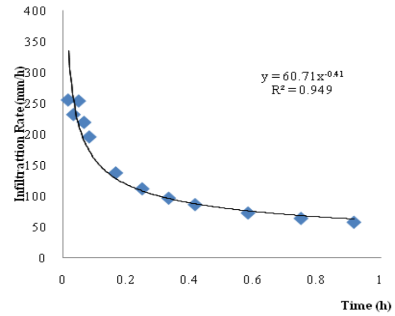


**Figure 5: Infiltration Rate of GDC**

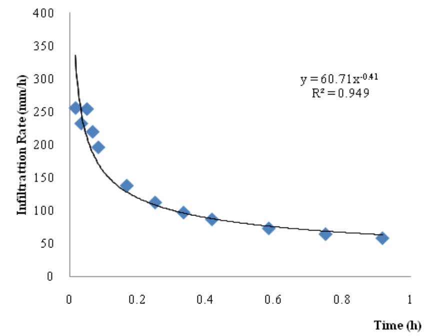


**Figure 6: Infiltration Rate of GUC**

The infiltration rate plots of Gumu disposal site plot C (Figure 5) was realized to be 52.97 mm/h which is considered as moderate compared to the non-disposal site plot C (Figure 6) which recorded an infiltration of rate of 72.59 mm/h and rated as moderate to rapid. The water retention ability of the non-disposal site plot C compared to the disposal site plot C indicates that the water retention ability of the soil will differ greatly when it rains.

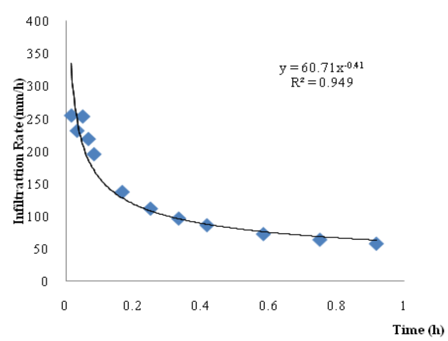


**Figure 7: Infiltration Rate of KDA**

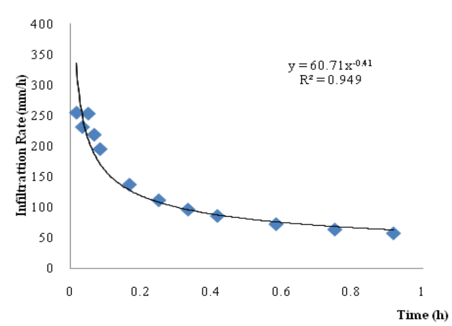


**Figure 8: Infiltration Rate of KUA**

Except Kasalgu non-disposal site plot A and B, the soils of the other study plots were sandy loam. At the Kasalgu disposal site plot A (Figure 7) and non-disposal site plot A (Figure 8) the infiltration rate of the soils was 57.97 mm/h indicating a moderate infiltration rate even though the soils classes were different. The effect of the Shea waste-slurry in changing the properties of the soil at the disposal site plot A which is sandy loam to the characteristics of loam therefore could account for this, as it is seen to be reducing the sandy characteristics of the soil.

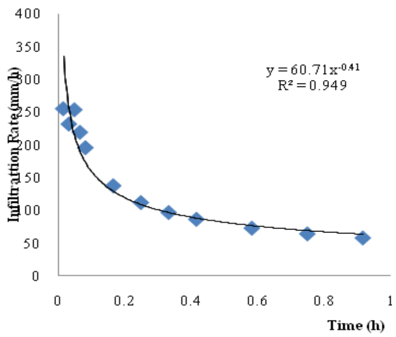


**Figure 9: Infiltration Rate of KDB**

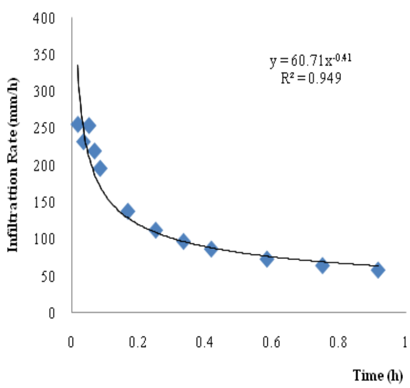


**Figure 10: Infiltration Rate of KUB**

Kasalgu disposal site plot B which has a soil type of sandy loam interestingly recorded the same infiltration rate of 57.67 mm/h as the non-disposal site plot B which is a sandy soil. The results may therefore be the same as a result of the presence of soil organisms burrowing and breaking down the soil organic matter and Shea waste-slurry. This has the potential of influencing the infiltration rate of the soils

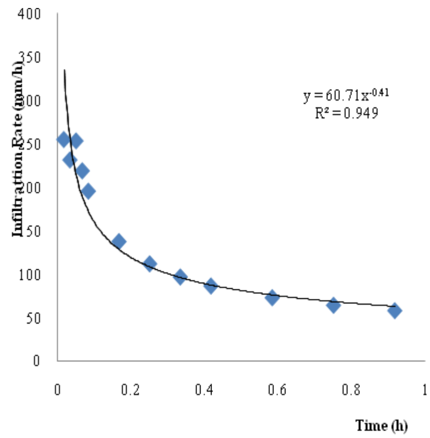


**Figure 11: Infiltration Rate of KDC**

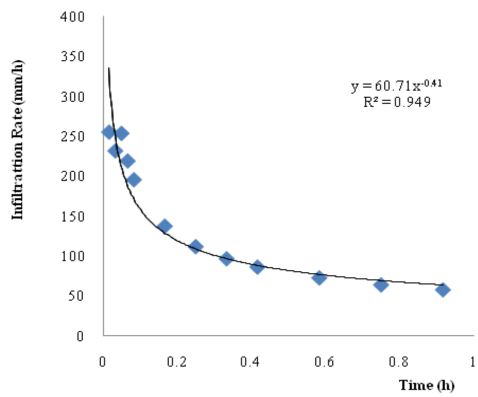


**Figure 12 : Infiltration Rate of KUC**

Figure 11 depicts a higher infiltration rate of 63.87 mm/h recorded at disposed site plot C which is considered as being moderate to rapid compare to an infiltration rate of 57.67 mm/h recorded at Kasalgu non-disposal site plot C Figure 12. The difference in infiltration rates of the plots could be attributed to differences in bulk density and the porosity of the soils as presented in Tables 1 and 2. According to Gerrard (2000), soils with high bulk density inhibit water movement and root penetration.

**Table 1: Geographical Location of Sampling Sites**

| Gumu | | Kasalgu | |
|---|---|---|---|
| **Disposal Site A** | **Non-disposal Site A** | **Disposal site A** | **Non-disposal Site A** |
| N $09^0$ 29' 58.1" | N $09^0$ 29' 59.6" | N $09^0$ 24' 17.4" | W $000^0$ 55' 18.6" |
| N $000^0$ 53' 594" | W 000' 53' 58.6" | W$000^0$ 55' 18.9" | N $09^0$ 24' 17.4" |
| **Disposal Site B** | **Non-disposal Site B** | **Disposal Site B** | **Non-disposal Site B** |
| N $09^0$ 290 56- 9" | N $09^0$ 29' 56.8" | N $09^0$ 24' 17.9" | W $000^0$ 55' 19.4" |
| W 000 '54'00.1" | W 000' 53' 59.0" | W $000^0$55' 19.6" | N $09^0$ 24' 18.6" |
| **Disposal Site C** | **Non-disposal Site C** | **Disposal Site C** | **Non-disposal Site C** |
| N $09^0$ 29 '58.2" | N $09^0$ 24' 18.9" | N $09^0$ 24' 18.4" | W $000^0$ 55' 20.2" |
| W 000. 53 '59.8" | W $000^0$ 55' 20.2" | W $000^0$ 55' 20.5" | N $09^0$ 24' 18.9" |

**Table 2: Bulk Density, Gravimetric Moisture Content, Volumetric Moisture Content and Porosity**

| Sampling Plot | Bulk Density ($g/cm^3$) | Gravimetric Water Content (g/g) | Volumetric Moisture Content (%) | Porosity (%) |
|---|---|---|---|---|
| GUA | 1.30 | 0.10 | 13.30 | 50.90 |
| GDA | 0.95 | 0.15 | 14.20 | 64.20 |
| GUB | 1.52 | 0.11 | 16.80 | 42.60 |
| GDB | 1.35 | 0.11 | 15.50 | 49.10 |
| GUC | 1.37 | 0.08 | 12.30 | 48.10 |
| GDC | 1.30 | 0.10 | 13.40 | 50.90 |
| KUA | 1.42 | 0.02 | 2.90 | 46.40 |
| KDA | 1.33 | 0.12 | 16.40 | 49.80 |
| KUB | 1.52 | 0.22 | 33.00 | 42.80 |
| KDB | 1.33 | 0.11 | 15.10 | 49.70 |
| KUC | 1.35 | 0.02 | 0.30 | 48.90 |
| KDC | 1.27 | 0.07 | 0.90 | 51.90 |

**Table 3: Particle Size Distribution of Disposed and Non-disposal Sites at Gumu and Kasalgu**

| Sampling Plot | % Sand | % Clay | % Silt | Texture | Porosity (%) |
|---|---|---|---|---|---|
| GDA | 80.92 | 6.6 | 12.48 | Loamy Sand | 50.90 |
| GUA | 78.92 | 6.6 | 14.48 | Loamy Sand | 64.20 |
| GDB | 76.92 | 6.6 | 16.48 | Loamy sand | 42.60 |
| GUB | 76.92 | 10.6 | 12.48 | Sandy Loam | 49.10 |
| GDC | 78.92 | 4.6 | 16.48 | Loamy Sand | 48.10 |
| GUC | 72.92 | 4.6 | 22.48 | Sandy Loam | 50.90 |
| KDA | 62.92 | 14.6 | 22.48 | Sandy Loam | 46.40 |
| KUA | 42.92 | 18.6 | 38.48 | Loam | 49.80 |
| KDB | 68.92 | 6.6 | 24.80 | Sandy Loam | 42.80 |
| KUB | 90.92 | 4.6 | 4.48 | Sand | 49.70 |
| KDC | 62.92 | 4.6 | 32.48 | Sandy Loam | 48.90 |
| KUC | 72.9 | 4.6 | 22.48 | Sandy Loam | 51.90 |

## Conclusions

The results of the study indicate that Shea waste-slurry generally has positive influence on soil physical properties. The study further revealed that Shea waste-slurry have the potential to decrease soil bulk density and infiltration rate, but increase total porosity, gravimetric and volumetric moisture content of soils in the savannah areas of Sub-Saharan Africa region. Reduced infiltration rate coupled with increased volumetric and gravimetric moisture contents have the potential of reducing nutrient leaching from soils and thus enhance nutrient uptake. Shea waste-slurry can therefore serve as a good source of organic matter and useable for the amendment of soil physical properties if it does not present adverse chemical properties. The use of Shea waste-slurry by farmers in improving soil physical properties should be encouraged.

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