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Full Length Research Paper

Characterization of soils in the Gamodubu landfill area in the Kweneng District, Botswana

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Understanding soil attributes guides arable farming initiatives in many countries, especially developing countries. In this study, soils of the Gamodubu area, in the Kweneng District, Botswana, were analysed to determine their suitability for arable farming. Soil organic matter (SOM) was estimated by determining soil organic carbon (SOC) times a factor. Five samples of soil were collected in the Gamodubu area for evaluation in the laboratory. There was positive correlation between soil organic matter and soil organic carbon of the 5 samples. Organic carbon percentages ranged from 3.44% to 4.90% while organic matter percentages ranged from 5.85% to 8.42%. The SOM/SOC ratios varied from 1.70 to 1.72 for the 5 soil samples. The pH among the soil samples ranged from 4.65 to 6.80 signalling slightly acidic to almost neutral pH conditions. Most plants grow in the 5.5 to 7.5 pH range. Luvisol soil group was found to be the dominant class in the study area rendering the soil in the area to be highly fertile. Loamy sand soil was found in four soil samples.The findings of this study will not only guide future arable farming assistance programmes by the government, but will also provide valuable reference information for future studies on the soils of the Gamodubu area.

Keywords: Soil organic matter, soil organic carbon, pH, electrical conductivity, characterization.

INTRODUCTION

Soil characterization is not a new phenomenon in Botswana. The Soil Mapping and Advisory Services project kick started the development of a legend of soils of Botswana through soil mapping exercises in the eastern part of Botswana. Soil characterization is an important exercise in the agricultural sector. Characterization of soil enables us to understand the biological, chemical and physical properties of the soil. This, in turn, enables us to determine the fertility of the soil for activities such as arable farming, horticulture, vegetable farming and others. Studying properties of soil is important because chemical and physical properties of soil offer support to the ecosystem (Ahn and Jones, 2013).

Morphological attributes of soil in a specific area are important in gauging the suitability of that soil for irrigation development. There are many factors that are considered during soil characterization. This includes the determination of soil structural stability. Structural stability pertains to the property of soil to allow water retention, support plant development while simultaneously giving protection to carbon in the soil (Field *et al*., 2006). Soil organic carbon (SOC) is the amount of carbon in the organic matter of the soil. Soil organic matter (SOM) comprises of varying particle sizes and carbon content.

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Municipal waste can contain organic matter which increases nutrients for plant growth (Amusan *et al*., 2005). Millions of wastes from residential homes, agricultural operations and sludge get into the soil and becomes part of the soil system thereby changing the physicochemical attributes of the soil (Piccolo and Mhanwu, 1997). This is however not the case in many developed countries where municipal waste is disposed of in scientifically designed sanitary landfills (Nagendran *et. Al.*, 2006). It has been reported that soil containing waste has high content of organic matter that will influence the degree of nutrient solubility present in the soil (Anikwe and Nwobodo, 2002).

SOM contains different components that decompose at different rates. Organic matter also possesses fulvic and humic acids and other functional groups which have cation exchange properties and can adsorb cations of metals (Bianchi *et al*., 2008). SOM provides some benefits to the soil. In addition to nutrients provision, SOM helps in the reduction of soil erosion as well as in increasing the stability of soil particles. Consequently, soil structure is enhanced which leads to better water retention and better aeration of the soil. Organic carbon enters the soil through different ways such as dead microbes, decomposing animals and plants. Organic carbon is an important component of soil characterization. Over the years, soil characterization has been done to examine and control carbon and greenhouse gases emissions (Tremblay *et al*., 2006; Ouimet *et al*., 2007) and also to determine the farming potential of soils.

There are different methods of analysing soil organic content (Tabatabai 1996). However, each of these methods has its advantages and disadvantages (Sollins *et al*., 1999). Some are more expensive than others, both in terms of operation and maintenance. Different methods of soil organic content analysis also have different levels of accuracy. Most studies about African soils are more focused on the analysis of terrestrial systems instead of investigating soil nutrition composition such as the amount of organic carbon in the soil (Pardo *et al*., 2003). This is despite the fact that there are still a sizable number of African countries that heavily rely on agriculture for self-sustenance and economic gain. Therefore, it is very important that studies like ours are conducted consistently not only to test for the nutritional value of soils but also to identify areas with fertile soils for farming purposes.

The aim of this study was to, for the first time, characterize and analyse the soils of the Gamodubu area in central Botswana for their ability to support arable farming. The organic and carbon matter of 5 randomly selected soil samples were determined. In addition, particle size variation, textural class, pH, electrical conductivity (EC), soil classification and soil colour of the soil samples were determined.

METHODS

Study Area

The site for this study was Gamodubu village (S: 24’ 29’ 30.3” E: 025’42’30.2”)in Kweneng District, Botswana. The study area is about 900meters above sea level and about 20 km from Molepolole to the west and 30 km from Gaborone (the capital of Botswana) to the east (Kweneng District Development Plan 6: 2003 – 2009). The mean annual rainfall of Gamodubu varies from 500mm to 600mm. Because of altitude, there are temperature variations in Gamodubu with 25-32.6^{0}C daily temperatures in summer and 15-20^{0}C in winter.

Geology and soils

Gamodubu area is characterized by the Kalahari group in the sandveld and surface sands and weathering residues in the hardveld. Shallow calcrete and ferricretes may also be present (Kweneng District Development Plan 6: 2003 – 2009). Landforms in the hardveld and sandveld depend on the main erosional and depositional processes that have been at work in the region. In the hardveld, the major landforms include hills and escarpments, which are associated with the prevailing rock types and rock structures and the fluvial networks. The rock types are subject to weathering of the bedrock and erosion by drainage networks and slope degradation (Kweneng District Development Plan 6: 2003 – 2009).

Soil analysis

Soil organic matter was determined as explained by Souza *et al*. (2016) who describe the Walkley-Black method of 1934. Five soil samples were randomly sampled, air-dried and ground to pass through a 2 mm stainless steel sieve to remove gravel and rock for analysis.For organic matter determination, briefly, 1g of each soil sample was added to 10ml of 1N potassium dichromate and 20ml concentrated sulphuric acid. This was incubated in a fume hood for 30 minutes. Then, 200ml distilled water and 10 ml phosphoric acid were added. This was then titrated with 0.5N ferrous ammonium sulphate, adding 5 ml of redox indicator when the solution had become greenish. The end point was reached when the solution colour changed from bluish purple to turquoise green. Organic matter was determined by multiplying in reverse the reciprocal of van Bemmelen factor of 0.58 (i.e. 1.724) and organic carbon value.

%Organic matter was determined by the following equations;

$$\%OC = 0.396/massofsoil \times \ [VolumeofK2Cr2O7 \times Normality] - [Vol.of \ \ (Fe\ (NH4)\ 2\ (SO4)\ 2 \times Normality]$$

$$\%\ Organic\ matter\ =\ 1.72\ x\ \%\ organic\ carbon\ (OC)$$

Soil particle size determination

Soil particle size was determined using a method by Ashworth *et al*. (2001) which is based on Bouyoucos hydrometer method of 1927. Briefly, oven-dried soil samples were mixed with 5% dispersing agent to disperse aggregates into individual particles. Then, 1000ml of water was added to the dispersed soil samples. Hydrometer readings were taken and at the same time, temperature readings of the soil suspensions were recorded. This was repeated three times and average readings were calculated.

The following equations were used to calculate the percentage of sand, silt, and clay in the soil samples (See Karkanis *et al*., 1991):

$$\%Clay = corrected hydrometer\ reading\ after\ 2hrs\ / mass\ of\ soil\ (50g)\ \times 100$$

$$\%silt = corrected hydrometer\ reading\ after\ 2hrs\ / mass\ of\ soil\ (50g)\ \times 100 - \%\ clay$$

$$\%sand = 100\ \% - (\ \%silt + \%\ clay)$$

Soil texture, colour, pH and EC determination

The weight % sand, silt and clay obtained were used to find texture classes of the soil samples using the texture triangle of soil which is used to distinguish different types of soil by breaking the distribution of particle sizes (soil textures) into 12 categories: clay, sandy clay, silty clay, sandy clay loam, clay loam, silty clay loam, sand, loamy sand, sandy loam, loam, silt loam and silt. Soil colour was determined as described by Kuehni (2001) which describes the Munsell Colour Charts of 1912. Munsell colour charts allow the visual identification and matching of colour based on a scientific approach. Soil pH was determined in calcium chloride which was mixed with soil at a 1:2 ratio. Air-dried soil samples were mixed with dilute (0.01M) calcium chloride ($CaCl_2$) two times their weight. pH was measured using an electrode. The results are usually expressed as pH ($CaCl_2$). Soil pH in distilled water was used in place of 0.01M calcium chloride, and results were expressed as pH (Water). Electrical Conductivity (EC) was measured using an electrical conductivity meter (See User's Guide, Extech Instruments, 2011) which uses the potentiometric method in H2O and CaCl2.

RESULTS

The percentage organic carbon for soil samples one to five were 3.99%, 3.44%, 4.90%, 4.82% and 4.79% respectively. Organic matter percentages for the samples were 6.86%, 5.85%, 8.42%, 8.29% and 8.24% (Figure 1). Organic carbon percentages ranged from 3.44% to 4.90% while organic matter percentages ranged from 5.85% to 8.42%. The SOM/SOC ratios for the five soil samples were 1.72, 1.70, 1.72, 1.72 and 1.72 from soil sample 1 to 5 respectively.

Sandy loam and loamy sand soils were the textural class found at the control site, and loamy sand was found in four soil samples while one soil sample was found to be sandy loam (Table 1). Sand was the dominant particle size in all the 5 soil samples while silt was present in low numbers in all the samples. Mean particle size values showed that sand was present at 77.0%, followed by clay at 13.5% and lastly silt at 8.6% (Figure 2). Soil colour analysis showed that ferric luvisols and haplic luvisols were the dominant soils found in Gamodubu area with dominant colours being brown and reddish brown (Table 1).

The pH values and electrical conductivity of the 5 soil samples were determined. pH values recorded were 5.23,5.12, 5.71, 4.65, and 6.80 respectively (Table 2). The highest pH recorded in the soil samples was 6.80, which was almost neutral while the lowest pH recorded was 4.65 which was slightly acidic. The EC values for the 5 soil samples were 20.33, 37.0, 48.220, 121.9 and 192.8 µS/cm respectively (Figure 3). The EC values in all the sample soils were less than the Botswana Bureau of Standard permissible limit (700µS/cm) of physical and organoleptic requirements of drinking water.

DISCUSSION

This study discovered that loamy sand was the dominant type of soil texture in the Gamodubu area. Soil texture can be influenced by factors such as the movement of cars and trucks. Indeed Gamodubu is located along the main road connecting Gaborone and Molepolole; therefore it experiences a lot of car movement due to stop overs and constant movement of delivery trucks into the village. In fact, visual observation showed that the soil texture was coarser away from the main road and finer near the main road. Animal movement is another influencing factor to soil texture. Gamodubu is a rural village where pastoral farming is still heavily practiced. During this study, animal tracks were observed ubiquitously in the village. It may be due to these factors that the heavily sandy soil texture in Gamodubu is slowly becoming loamy.

According to the Food Agricultural Organization (FAO) World Soil Map, revised legend (1989), 7 soil groups (leptosols, vertisols, arenosols, regosols, calcisol, luvisol, lixisols) and 13 soil units have been identified in the Kweneng District. This study discovered that ferric luvisols and haplic luvisols were the most dominant soils found in the study area. According to the Kweneng District Land Use Plan (2002), luvisols have sub-surface accumulation of low activity clays and high base saturation. Botswana Soil Legend characterized ferric luvisols as moderately deep to very deep, moderately well to well drained. These attributes make these soils ideal for arable farming. Luvisols extend over 500–600 million ha worldwide. In subtropical and tropical regions, luvisols occur mainly on young land surfaces. According to the World Soil Resources Reports (2001), most luvisols are fertile soils and suitable for a wide range of agricultural uses. All soils in this study were determined to be luvisols, an indication that they can be used for arable farming. However, luvisols with a high silt content are susceptible to struc-

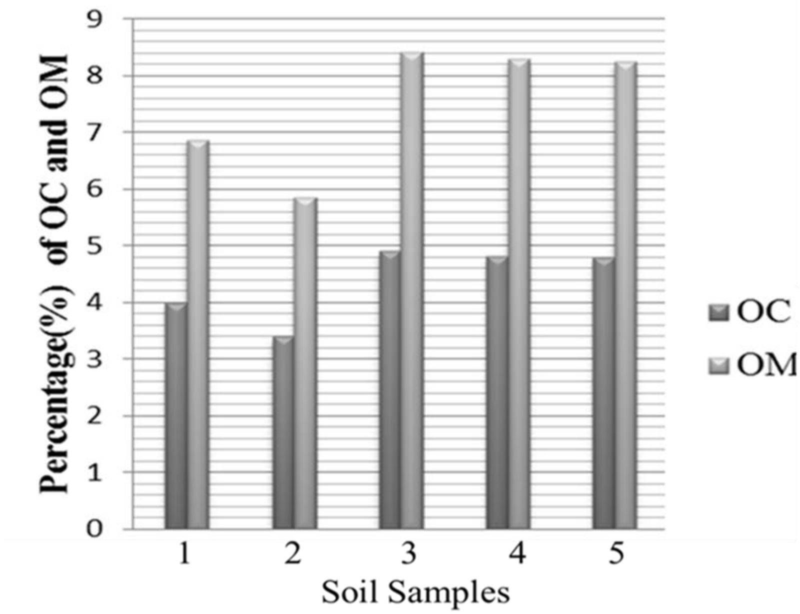

Fig 1. Percentage OM and OC of 5 soil samples in the Gamodubu area.

Table 1. Classes, texture and colour of the five soil samples in the Gamodubu area.

Soil Samples	**%Clay**	**%Silt**	**%Sand**	**Textural Class**	**Soil Class (FAO)**	**Soil Colour Description**
1	13.0	11	76	Sandy Loam	Ferric luvisols (A11)	Reddish Brown
2	15.0	9.0	76	Loamy Sand	Haplic luvisols (LVh)	Brown
3	13.0	9.0	78	Loamy Sand	Haplic luvisols (LVh)	Brown
4	15.6	6.4	73.4	Loamy Sand	Haplic luvisols (LVh)	Brown
5	11.0	7.6	81.4	Loamy Sand	Haplic luvisols (LVh)	Brown
Mean	13.5	8.6	77.0			

ural deterioration when tilled with wet or with heavy machinery. Mean percentage silt particle size was very low in this study; therefore, soils in the Gamodubu area might be structurally stable. Truncated luvisols are in many instances better soils for farming than original, non-eroded soils. The World Soil Resources Reports, (2001) showed that luvisols in temperate zones are widely used to grow small grains, sugar beet and fodder. Luvisols in sloping areas are used for orchards and as forests for grazing.

Soil colour is particularly helpful in determining attributes of soil that would otherwise be difficult to measure. It can guide studies of land use and soil formation. Gamodubu soils were found to be brown and reddish brown, which could have been due to the influence of parent material. These colours could also signal the presence of iron oxide in the soil. Sometimes dark soil colour can be a result of organic matter decomposition. Red and brown are strong pigments that can give soils orange, red, yellow, or brown colours even at low concentrations (Cornell and Schwertmann, 2003). Colour samples in this study were brown or reddish brown, an indication of high organic matter content.

Many factors, such as household waste can cause alterations in pH, nitrogen content and cation exchange in soil (Ward, *et. al.*, 2005). pH values on samples in this study were within acceptable limits as recommended by Botswana Bureau of Standards. Soil electrical conductivity (EC) is a measurement that correlates strongly to soil particle size and texture (Grisso *et al.*, 2009). The electrical conductivity of soils varies depending on the amount of moisture held by soil particles. Sands have a low conductivity, silts have a medium conductivity, and clays have high conductivity.

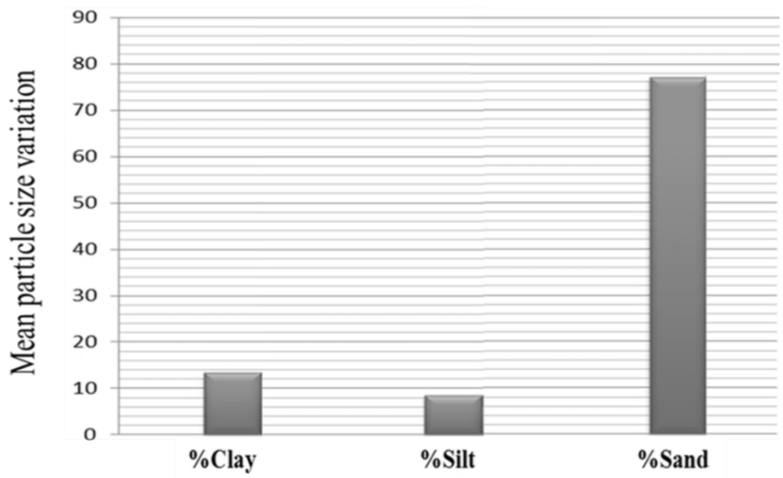

Fig 2. Mean soil particle size variation of soils in the Gamodubu area.

Table 2. pH Water, and pH $CaCl_2$of the 5 soil samples (Source BOS 32:2009).

Soil sample	**pH H_2O**	**pH $CaCl_2$**
1	5.23	4.64
2	5.12	4.43
3	5.71	4.84
4	4.65	5.17
5	6.80	5.80
Water samples		
Control	7.88	

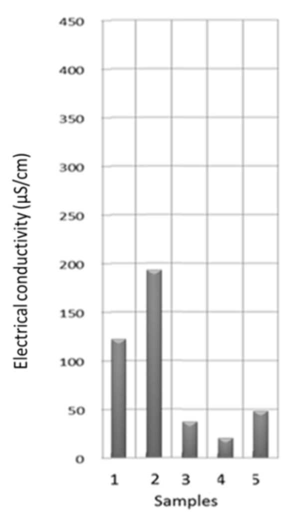

Fig. 3. EC variations in 5 soil samples in the Gamodubu area.

Electric conductivity gives an idea about the presence of charged ionic species in the water solution. In this study, the EC values of the soil samples were much lower than Botswana Bureau of Standards permissible limits of physical

CONCLUSIONS AND RECOMMENDATIONS

and organoleptic requirement of drinking waterSource (BOS 32:2009) which is 700µS/cm. This means that water in these samples is free from pollution and therefore suitable for consumption.

In conclusion, five sample soils in the Gamodubu area in Botswana were characterized for their suitability to plant farming. The SOM/SOC ratios of these samples varied between 1.70 and 1.72. Textural classes of soils in the

Gamodubu soils were loamy sand. These soils are often deficient in specific micronutrients and may require additional fertilization to support healthy plant growth. These soils were found to belong to the luvisol group of soils which permit and favour arable farming. The pH and EC values of the soils samples were determined. Soil pH is low in Gamodubu soils, and this pH was mainly slightly acidic. Electrical Conductivity was also noted to be fluctuating with no significant differences between the values. The EC values were found to be within the permissible limit as set out by the Botswana Bureau of Standards. Collectively, the findings of this study show the capacity of the soils in the Gamodubu area to support arable farming. This study has provided new information that has never been sought before. This study will guide plant farming decisions concerning the Gamodubu area. Moreover, this study can be used as a template to other future similar studies in Botswana.

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