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# Enhancing Soil Nutrient Status using Dynamic Kraaling Strategy in Northern Ghana

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**ABSTRACT**

Soil fertility depletion is a single most important constraint to food security in West Africa due to continuous cropping and increasing population pressure. Rising costs of commercial fertilizers and increasing emphasis on sound manure management to protect water quality, renewed interest has been focused on maximizing the fertility returns of organic manure. The study determined the effect of dynamic kraaling on soil nutrient status of soils of the middle voltain formation (sandstone, shale and siltstone) in Savelugu/Nanton District in the Northern Region of Ghana. Six (6) soil samples each were collected at two depths (0-40 cm and 40-80 cm) from an active kraal (AK), an old kraal (OK) and non-kraal (NK) farmlands. Laboratory soil analysis indicated that N levels were higher at 0-40 cm depth compared to the depth of 40-80 cm for the AK and the OK but indifferent for the NK farmlands at the two depths. High level difference in the concentration of Phosphorus (P) and Potassium (K) was observed between the two depths for AK and OK. The concentration of P and K was noted to have increased from the 0-40 cm depth to 40-80 cm depth. The results indicate that NPK was high in active kraals, old kraals and non-kraaled farmlands in decreasing order. Varying levels of organic matter (OM), organic carbon (OC), soil pH and electrical conductivity (EC) were also observed for the different kraaling systems but these were observed to be much higher for the active kraals. The effect of dynamic kraaling in the improvement of soil nutrient levels was high.



## Introduction

Soil is the collection of natural bodies occupying part of the earth's surface that support plants and that have properties due to the integrated effect of climate and biological activities upon parent materials, as conditioned by relief, over period of time (Brady, 1990).

Soil retains nutrients against loss to leaching and provides a habitat for soil organisms which have an essential role in the recycling of carbon and plant nutrients (Laegreid *et al*., 1999). Soil fertility is thus part of biological system in which soils, climates and plants interact.

An intensification of agricultural production on a global scale is necessary in order to secure food supply for an increasing population. Fallow periods are also reduced in farming system of the humid tropics. This leads to irreversible soil degradation and an increase in the destruction of the remaining natural forest due to the cultivation of new areas after slash and burn (Vosti *et al*., 2001).

The input cost of chemical fertilizers scares resource poor farmers who farm purposely to feed the family. Chemical fertilizers are expensive for resource poor farmers who often utilise their land for food production (Jansen *et al*., 2004). To effectively reverse the trend of declining productivity would require soil fertility replenishment. Effective soil fertility management holds the key to enhancing food production (Eghball *et al*., 2001).

Due to the continuous decline of soil fertility and productivity, expensive nature of mineral fertilizer and pressures on lands, it is essential to encourage the use of locally organic fertilizer to reclaim the soil fertility to meet the food need of the growing population. The uses of organic manure are not only cheaper alternatives to chemical fertilizers, but are capable of supplying nutrients and improving soil properties through the organic matter they contain (Awiti, 2002).

The use of kraals for keeping especially cattle characterise the study area. The reasons for keeping the animals in kraals include; confinement for milk extraction, for manure production (organic fertilizer) to enhance crop production and for protection against theft and wild animals. Kraaling systems have been largely used for accumulating animal droppings especially for enhancing the nutrient levels of soils for annual crop production. The study analysed the effect of dynamic kraaling on soil nutrient status in different kraals in Northern Ghana.

## Materials and Methods

### Study Area

Pong is a community located in the Guinea Savanna woodland of the Savelugu/Nanton District of the Northern Region of Ghana. The District occupies approximately 1,790.70 square kilometres. The District is generally flat with gentle undulating low relief. The Middle and Upper Voltaian sedimentary formation characterise the geology of the District. The middle Voltaian covers the northern part of the District and comprises of sandstone, shale and siltstone. The Upper Voltaian covers the southern part of the District and consists of shale and mudstone. The area receives an annual rainfall of 1,100 mm with a maximum temperature of 42 °C and minimum of 16 °C. The woodland zone support livestock farming, as well as the cultivation of staple crops like rice, groundnut, maize, yam, cowpea and vegetables (Savelugu/Nanton District Assembly, 2012).

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**Soil sampling and Analysis**

Soil samples were taken at the beginning of the raining season in June, 2012. Materials used in the field include earth chisel, polythene bags, ruler and GPS. Six (6) soil samples were taken, each from active kraal (AK), old kraal (OK) and non-kraal (NK) making a total of eighteen (18) samples for chemical analysis in the laboratory. Soils were sampled at three (3) randomly located points each in the AK, OK and NK farmlands at two depths of 0-40 cm and 40-80 cm given a total of twelve (12) soil samples.

**Table 1. Soil Sampling Locations**

| Kraal Type | Sampling Points | Location | | |
|---|---|---|---|---|
| | | Latitude | Longitude | Elevation (m) |
| Active Kraal (AK) | 1 | 09.70668$^o$ | 000.82779$^o$ | 133 |
| | 2 | 09.70685$^o$ | 000.82794$^o$ | 132 |
| | 3 | 09.70708$^o$ | 000.82794$^o$ | 132 |
| Old Kraal (OK) | 1 | 09.70653$^o$ | 000.82791$^o$ | 133 |
| | 2 | 09.70642$^o$ | 000.82790$^o$ | 131 |
| | 3 | 09.70625$^o$ | 000.82798$^o$ | 131 |
| Non-kraal (NK) | 1 | 09.70603$^o$ | 000.83039$^o$ | 127 |
| | 2 | 09.70611$^o$ | 000.83045$^o$ | 133 |
| | 3 | 09.70633$^o$ | 000.82794$^o$ | 132 |

**Major Soil Nutrients Determination**

Total nitrogen was determined by the Kjeldahl method whilst available phosphorus was determined on a spectrophotometer by the blue ammonium molybdate method with ascorbic acid as reducing agent. Available potassium extracted using the Bray's no. 1 solution was determined directly using the Gallenkamp flame analyzer.

**Soil Exchangeable Bases Determination**

Soil exchangeable bases were determined using the Ammonium acetate method.

**Soil Organic Carbon**

The determination of soil organic carbon was based on the Walkley-Black chromic acid wet oxidation method.

**Electrical Conductivity Determination**

5 g of soil sample was weighed into a 50 ml beaker and 25 ml of distilled water was added. The suspension was stirred for 1 hour, after which conductivity meter was calibrated to a reading of 1.412 mS/cm of KCl. Reading of the soil suspension was taken and the value recorded.

**Soil pH**

Soil pH was measured in a 1:1 soil-water ratio using a glass electrode (H19017 Microprocessor) pH meter.

**Results and Discussions**

**Characteristics of Soil and Kraaling Systems**

The middle and upper voltaian sedimentary formation characterize the geology of the study area with the common soil types being siltstone and mudstone.

Kraals are characterized by thick accumulations of young and old manure which constitute nutrient over-enrichment and a major point source of environmental pollution (Kizza *et al.*, 2010).

The use of kraals in traditional livestock management system has been widely investigated, with most studies tending to focus on the importance as nutrient reserves that can be exploited to support crop production (Kangalawe *et al.*, 2008).

The systems used in the area for the kraaling of the cattle were observed as 'compound kraaling' and 'farm field kraaling'. With the compound kraaling, the main objective is protection of cattle against theft and later conveyance of the animal droppings to farm fields. The urine component of the waste products of the animals is usually lost when compound kraaling is adopted. 'Farm field kraaling' involves kraaling the animals on the farm fields and rotating them in a dynamic manner commonly referred to as 'dynamic kraaling'. Dynamic kraaling is therefore a system of keeping cattle in temporary ranches usually farmlands, and rotating them with the main aim of accumulating the droppings and urine of the animals which have fertilizer value to improve soil fertility for annual crop production. In dynamic kraaling system, two methods are adopted thus active kraaling (undertaken at the onset of the raining season of the same year of crop cultivation) and old kraaling (practiced at the onset of the lean or dry season).

According to Xaxagbe (2003), dynamic kraaling is the practice of rotating animals (mostly livestock) on the farm from spot to spot for the purpose of collecting their droppings and urine in situ to fertilize the soil.

The manure produced by these animals contain the same nutrient element found in mineral fertilizers but varies in the amount supplied to the soil and also gives good soil amendment providing better soil physical properties thus, improving aeration, drainage, structure, etc (Mbatha, 2008).

The kraal disrupt the natural nutrient cycle by locking up nutrient at confirmed localities in pastoral systems where manure is not harvested to improve soil fertility (Augustine, 2003).

**Effect of Dynamic Kraaling on Soil Macronutrient**

An element at a low level many cause deficiency symptoms while the same element at a higher level may cause toxicity (Uchida, 2000).

Soil analysis from the active, old and non-kraal samples indicated high levels of nitrogen (N), phosphorus (P) and potassium (K) in the soils for active kraals compared to the old kraals with very low levels observed in non-kraaled sites.

Among the essential elements needed by crops, nitrogen is the element that limits growth the most. Nitrogen deficiency is also more likely to occur where immature compost is used since microbes use nitrogen during the breakdown of organic material, which is supposed to be used by the plants (Lampkin, 2000 and FSSA, 2003).

The practice of kraaling in the study was noted to increase the nitrogen content in soils as can be observed from Table 1 which indicates that both kraals recorded higher N levels compared to surrounding non-kraal soils. Non-kraal soils at both depths recorded the same N level and the increase in N level in the active and non-kraaled sites indicates the positive effect of kraaling on the soil nutrient level.

The low levels of the recorded N levels of the study can therefore be attributed to the reasons mention by Murwira (1995) and Markewich *et al*. (2010).

According to Nzuma and Murwira (2000) addition of bedding material in kraals is an important management practice which helps to keep kraals dry. The practice increases the amount of manure and prevents excessive loss of nutrients like nitrogen.

According to Brady and Weil (1999) deficiency symptoms of nitrogen include pale yellowish green colour (chlorosis), stunting and thin, spindly stems.

Phosphorus which is a major limiting nutrient in the soil of the savanna ecosystem was observed to be high especially increasing from 2 meq/100g in the non-kraaled areas to 71 meq/100g in the active kraals for the 0 - 40 depth. High levels of P were however noted to be at the depth of 40 - 80 cm for the non-kraaled areas. This will however not be readily available for uptake and use by crop plants especially the vegetable crops which are commonly grown in these areas due to the shallow roots. For maize cultivation, depth will not be a limiting factor in the utilization of P. Mao *et al*. (2008) and Olowolafe (2008) observed a higher phosphorus content of the soil where cattle manure or municipal waste was used for a period of 5 years on maize compared to inorganic fertilised soil.

**Table 2. Variations in Nutrient Content of Manure**

| Organic fertilizer Reference | Nutrients (%) N | P | K |
|---|---|---|---|
| Kraal manure Lampkin (2000) | 1 | 0.8 | 2 |
| Raw cattle manure FSSA (2003) | 1.1 | 0.4 | 1 |
| Composted cattle manure FSSA (2003) | 1.6 - 2.2 | 0.6 - 1.2 | 1-1.3 |
| Cattle manure (fresh) Boyhan *et al*. (1999) | 25 | 15 | 25 |

Eghball and Power (1999) reported an accumulation of soil P as a result of kraal manure application. Moreover Kizza and Areola (2010) in their studies noted that characteristic soil alkalinity within kraals is consistent with the high OM content which likely influenced the observed elevated concentrations of phosphorus and total quantities of soluble exchangeable bases. A phosphorous-deficient plant has been reported to be usually stunted, thin-stemmed, and spindly, but its foliage is often dark, almost bluish, and green. In severe cases, phosphorous deficiency can cause yellowing and senescence of leaves (Brady and Weil, 1999). Table 3 presents the detailed primary soil nutrients for the two depths.

**Table 3. Primary Nutrient Level in Sampled Fields**

| Kraal Type/Soil Nutrient | N (%) 0-40cm | N (%) 40-80cm | P (meq/100g) 0-40cm | P (meq/100g) 40-80cm | K (meq/100g) 0-40cm | K (meq/100g) 40-80cm |
|---|---|---|---|---|---|---|
| Active kraal | 0.110 | 0.036 | 71 | 4.8 | 1.60 | 0.80 |
| Old kraal | 0.133 | 0.026 | 28 | 3.6 | 1.14 | 0.537 |
| Non-kraal | 0.020 | 0.020 | 2 | 8.1 | 0.39 | 0.380 |

Potassium levels in the active kraal, old kraal and non-kraal sites recorded increased in a similar fashion like the other nutrients in the order of highest being active kraal, old kraal and non-kraal being the least.

According to Okalebo and Woomer (2005) potassium may be lost from manure through leaching action of rainwater.

Application of manure can result in increase soil concentration of nutrient and organic matter (Eghball, 2002).The richness of animal manure nutrient depends on the feed the animal eats. The richer the feed in proteins, the richer the manure is in nitrogen. Similarly, the more phosphorous and potassium in the feed, the more of these constituents there are in the organic fertilizer (Lampkin, 2000). Soil applied organic fertiliser assists in maintaining soil moisture regimes which are considered to be favourable for plant growth (Gupta, 1987).

Microbes use nitrogen to breakdown the manure to release the nutrient. The application of organic fertilizer also increases the populations of micro-organisms in the soil that helps the soil to release various nutrients. These micro-organisms also produce plant growth regulators that are important for plant growth and photosynthetic activity (Levy and Taylor, 2003; Walker and Bernal, 2004).

**Soil Micro Nutrients**

These are nutrient element required by plant in relatively small amount. In their absence a plant is not likely to complete its life cycle. They include Calcium (Ca), Magnesium (Mg), etc. Figure 1 presents the secondary soil nutrients of the sampled soils.

Magnesium was high in the soils of the kraaled sites than the non-kraaled sites with the active kraal being slightly higher (Figure 1). Magnesium is essential for the production of the green pigment in chlorophyll, essential part of plant cell wall structure, provides for normal transport and retention of other elements as well as strength in the plant, counteract the effect of alkali salts and organic acids within a plant (Brady and Weil, 1999). Keren (1991) reported that increases in exchangeable Mg levels may influence water infiltration rates negatively in arid and semi-arid regions by causing the soil surface to seal.

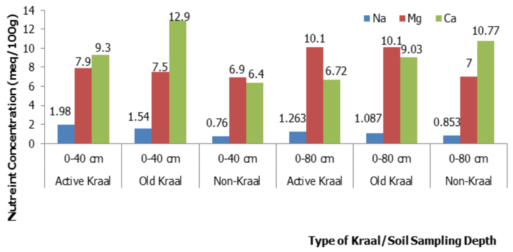


Figure 1: Secondary Nutreint Concentration

Total Calcium level was high in old kraal (12.9 meq/100g) followed by active kraal (9.3 meq/100g) and non-kraal field (6.4 meq/100g) in the 0 - 40 cm depth and the non-kraaled site recording very high levels at 10.77 meq/100g and the active and old kraals recording 6.72 meq/100g and 9.03 meq/100g respectively.

Calcium is a constituent of cell walls, involved in production of new growing points and root tips, it provides elasticity and expansion of cell walls, which keeps growing points from becoming rigid, it acts as a base for neutralizing organic acids generated during the growing process and aids in carbohydrate translocation and nitrogen absorption (Brady and Weil, 1999).

According to Uchida (2000), the calcium that is adsorbed to soil particles helps in stabilizing the soil structure. Adsorbed sodium might cause the soil to crack when dry and swell up when wet. Calcium replaces the adsorbed sodium and prevents damages to soil structure.

Sodium was observed to be high in both depths of AK and OK as presented in Figure 1 whilst lower levels were recorded for both depths of the NK.

**Other Soil Properties**

According to Grisso *et al*., (2009), electrical Conductivity is a measurement that correlates with soil properties that affect crop productivity, including soil texture, cation exchange capacity, drainage conditions, organic matter levels, salinity and subsoil characteristics.

**Table 4. Other Soil Properties**

| Kraals/Soil Sampling Depth | EC (µs/cm) 0-40 cm | EC (µs/cm) 40-80 cm | Organic Carbon (%) 0-40 cm | Organic Carbon (%) 40-80 cm | Organic Matter (%) 0-40 cm | Organic Matter (%) 40-80 cm | pH 0-40 cm | pH 40-80 cm |
|---|---|---|---|---|---|---|---|---|
| **Active Kraal** | 192 | 89 | 1.31 | 0.387 | 2.25 | 0.67 | 8 | 7.8 |
| **Old Kraal** | 175.7 | 134 | 1.57 | 0.317 | 2.7 | 0.54 | 7.8 | 8.1 |
| **Non-Kraal** | 37.4 | 31 | 0.18 | 0.17 | 0.31 | 0.26 | 7 | 7 |

Soils taken from active kraal, old kraal and non-kraal at 0 - 40 cm recorded 192 µS/cm, 175.7 µS/cm and 37.4 µS/cm respectively. At 40-80 cm active kraal, old kraal and non-kraal recorded 89 µS/cm, 134 µS/cm and 31 µS/cm respectively (Table 4). Electrical Conductivity has been noted to help in the mobility and uptake of nutrients by plants and these values play that significant role.

Chang *et al*., (1991) reported that EC of the soil increases with increasing rates of manure under irrigated conditions and under non-irrigated conditions. Soils with poor drainage are most susceptible to salt build-up as the salts are not leached from the root zone.

Soil organic carbon consists of a mixture of plant and animal residues at various stages of decomposition, of substances synthesized microbiologically and or chemically from the breakdown products, and of the bodies of live microorganisms and small animal. Organic carbon protects soil against erosion and also decomposes to add nutrient to the soil.

With respect to the depth of 0 - 40 cm, high levels of organic carbon compared to the depth of 40 - 80 cm was observed and this may be due to the concentration of manure at the surface. The variation of levels of organic carbon among kraals may be due to management practice or the length of time the manure has been in the soil. Chamber *et al*. (2001) reported that, if handled properly, manure is a significant nutrient resource for soil. For example, fresh cattle manure can contain up to 50 to 80% of the N and P originally in the feed.

Soil organic matter is an essential component of soil, contributing to the biological, chemical and physical properties; aids nutrient storage and nutrient availability by increasing the soil CEC, providing chelates and increasing the solubility of certain nutrients in the soil solution (Sommerfeldt, 1988).

In soil with an effective rooting depth of less than 300 mm (shallow soils) the application of organic fertilisers is less effective because the growth of roots to deeper layers is restricted**.** Most of the organic matter and nutrients are found in the top layer of the soil, but plant roots can also extract nutrients from the subsoil. If the soils are shallow, the roots have to get all the nutrients and water from the top soil (Mbatha, 2008).

Active kraal recorded lower organic matter compared to old kraal and this may be attributed to manure not decomposed whiles for old kraals may be due to the decomposition which is made available to the soil. Also Zech *et al*., (1997) reported that a continuous addition of organic matter to the soil at kraals that had been actively utilised for many years influences the decomposition and mineralisation rates of the organic matter. Organic matter plays a vital role in the soil. Li (2008) reported that the incorporation of cow manure to paddy soils in China reduced the concentration of available Pb and Cd by 76.1% and 25.7% respectively.

In most soils, the organic matter accounts for less than about 5% of the volume (Mbatha, 2008).

A pH ranging between 5.5 and 7.0 is best for growth of most plants (Hudson *et al*., 1990).

Too acid or too alkaline soils create an unfavourable balance between acid and alkaline elements needed by the plants and it has a toxic effect on plants. Indirectly, soil acidity inhibits the availability of essential elements and reduces the activities of micro-organisms (Hue, 1992).

Soil pH is an easily measured soil property that is closely related to soil quality and productivity. Very low pH values, indicative of acidity, are associated with adverse soil conditions including reduced microbial activity, increased availability and toxicity of elements such as aluminium and heavy metals, and reduced availability of plant nutrients such as phosphorus. On the other hand, high pH values, indicative of alkalinity, can also pose problems by reducing the availability of many micronutrient metals and other plant nutrients (Schoenau, 2011).

Chang *et al*., (1991) reported that the ability of manure application to induce a change in soil pH will depend on its content of buffering agents such as carbonates and organic matter, as well as the production of organic acids and acidity during decomposition.

**Conclusions**

The results from the study reveal that kraal manure is a potential source of plant nutrient and as a soil conditioner.

Animal manure is a bio-resource that should be economically utilized. This is because it contains all the essential elements for plant growth, helps in the minimization of environmental pollution and reduces the hazards associated with the use of synthetic fertilizers.

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