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EFFECTS OF SOIL AND WATER CONSERVATION TECHNIQUES ON PHYSICAL AND CHEMICAL PROPERTIES OF SOIL IN THE SAVANNAH ECOLOGICAL ZONE

BY

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(MPhil. SOIL AND WATER CONSERVATION AND MANAGEMENT)

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THIS THESIS IS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL MECHANISATION AND IRRIGATION TECHNOLOGY, FACULTY OF AGRICULTURE IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN SOIL AND WATER CONSERVATION AND MANAGEMENT

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DECLARATION

I, Precious Kwaku Blege, author of this thesis titled, "Effects of soil and water conservation techniques on physical and chemical properties of soil in the savannah ecological zone, "do hereby declare that with the exception of references literature which have been duly acknowledged, this thesis is a result of research solely conducted by me from August 2012 to July 2013 in the Department of Agricultural Mechanization and Irrigation Technology of the Faculty of Agriculture of the University for Development Studies. This work has neither in part nor in whole been published nor presented to this University or elsewhere for an academic degree.

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DEDICATION

This thesis is dedicated to the Almighty God for His grace and guidance throughout my academic pursuit. I further dedicate this work to my father the late Christopher Blege, Mrs. Blege Harding Sarah and Maj. Rtd Samuel Azadze for their love, care and constructive advice.

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ABSTRACT

Soil and water conservation technologies are practiced in Northern Ghana to help farmers reduce food insecurity and promote sustainable agriculture. This work seeks to understand the effects of soil and water conservation techniques on the physical and chemical properties of soils in the savannah ecological zone. Three and two communities in the Kumbungu district and Kasena Nankani East Municipality, respectively, were selected for the study. Rainfall data from 1977 to 2012 was analysed for erosivity using modified Fournier index and soil samples were collected and analysed for physical and chemical properties. Generally very rapid rate of infiltration occur, downstream whiles rapid infiltration occurs upstream. Bulk density, porosity, organic carbon, soil organic matter and carbon accumulation values ranged from $1.58 g/cm^3$-$1.72\ g/cm^3$, 34 %-41 %, 4.6 g/kg- 6.4 g/kg, 0.79 g/kg-0.98 g/kg and 2.31 t/ha – 3.65 t/ha, respectively in the Tolon district. pH, Nitrogen, Phosphorus, potassium and CEC ranged from 5.27 – 5.56. 0.04 % – 0.05 %, 1.67 g/kg– 3.14 g/kg, 0.09 $cmol^+$/kg-0.17 $cmol^+$/kg to 2.15 $cmol^+$/kg- 5.21 $cmol^+$/kg, respectively Kumbungu district. Bulk density, porosity, OC, SOM and Cc values ranged from $1.67 g/cm^3$-$1.83\ g/cm^3$, 22 %-36 %, 5.3 g/kg- 7 g/kg, 0.91 g/kg-1.2 g/kg and 2.84 t/ha – 3.83 t/ha, respectively in the Kasena Nankani East Municipality. pH, Nitrogen, Phosphorus, potassium and CEC ranged from 4.92 – 5.62. 0.04 % – 0.05 %, 3.71 g/kg– 4.63 g/kg, 0.07 $cmol^+$/kg-0.13 cmol/kg to 2.13 cmol/kg- 8.36 cmol/kg, respectively Kasena Nankani East Municipality. Nutrient contents were generally low in soil sampled at the selected communities. Mean annual rainfall was 992 mm for 35 years, with highest rainfall occurring in 1999 with amount 1353 mm and lowest recorded 1995, with an amount of 688 mm for Kasena Nankani East Municipality, while 1147 mm for Tolon district the highest rainfall was recorded in 1999, with an amount of 1898.2 mm and the lowest occurring in 2005 with an amount of 749 mm. Mean Modified Fournier Index were 199 and 61 for Kasena Nankani East Municipality and Kumbugu district, respectively. In conclusion, soil nutrients were generally low among soils sampled at the selected communities as compared to the pre-data. It is recommended that farmers practice more of SWCT introduced by CPWF.

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LIST OF ACRONYMS

°C	Degrees Celcius
ADP	Adenosine diphosphate
AEZ	Agro-ecological Zone
ASFG	Aggrand Soil Fertility Guide
ATP	Adenosine triphosphate
Ca	Calcium
CEC	Cation Exchange Capacity
cm/h	Centimetre per hour
Cmol/kg	Centimol per kilogram
CPWF	Challenge Project on Water and Food
CSIR	Centre for Scientific Institute Research
Cu	Copper
DS	Downstream
Ecof	Eco-sahelian farm
EDTA	Ethylene diaminetetraacetic acid
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organisation
$FeSO_4$	Ferrous sulphate
g/cm^3	Grams per cubic centimetre
g/kg	Grams per kilogram
HCl	Hydrochloric acid
HA	Null hypothesis
ha	Hectare
H0	Alternate hypothesis
H_2SO_4	Sulphuric Acid
H_3BO_3	Trihydroxidoboron

K	Potassium
$K_2Cr_2O_7$	potassium dichromate
K.E	Kinetic energy
kg/ha	Kilogram per hectare
Mcf	Moisture correction factor
Meg/100 kg	Milligrams equivalent per 100 kilograms
MFI	Modified Fournier Index
MoFA	Ministry of Food and Agriculture
mg/kg	Milligram per kilogram
mm/h	Millimetres per hour
N	Nitrogen
NaOH	Sodium Hydro-oxide
NH_4OAc	Ammonium acetate
NRCS	Natural Resource Conservation Service
NO^{-3}	Nitrate Ion
OC	Organic Carbon
P	Phosphorous
ppm	Parts per million
RELC	Research Extension Farmer Linkages Committee
SARI	Savannah Agricultural Research Institute
SOM	Soil Organic Matter
SWC	Soil and Water Conservation
SWCT	Soil and Water Conservation Technology
t/ha	Tonnes per hectare
US	Upstream
USDA	United States Department of Agriculture

LIST OF EQUATIONS

CHAPTER ONE: INTRODUCTION

1.1 Background

Agriculture is the greatest contributor to Ghana's revenue and the main survival resource of the people. It is greatly affected by the quality of the soil and climate variability. Developing countries have to meet the food needs of its growing human populations. There is therefore the need for increased soil productivity. The productivity of a soil is linked directly with its fertility status. The effectiveness of the soil in producing adequate quantities of food and fibre depends primarily on its fertility status, which is defined as the ability of the soil to support crop growth by ensuring adequate and balanced supply of essential soil nutrients (Asiamah, 2009).

Soil infertility has been the fundamental cause for declining per capita food production in the tropics (Smaling *et al.* 1997; Sanchez and Palm, 1996). Food production in Ghana will not increase, unless soil fertility decline is effectively addressed. Most of the challenges of soil fertility decline have consequences such as severe socio-economic constraints.

The biodiversity of the savannas is relatively low, and it is further reduced by their extensive annual burning, and the proportion of trees and grass, which is inherently unstable. Therefore, changes in land use can have an impact on biomass and soil properties. Soil plays a vital role in providing food for the humans, as it supports and facilitates 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).

In the tropical savannah region of Ghana the predominant clay minerals in the soils are kaolinitic with low cation exchange capacity. Organic matter is very closely associated with the soils nutrient levels, because it has high cation exchange capacity (CEC) (Nye and Stephens, 1962). MoFA (2010) reported that soils found in northern Ghana are shallow and low in soil fertility, with low organic matter content, and predominantly coarse textured. Soils are further marked by declining soil fertility and high level of environmental and land degradation (bush fires, fragmented land, deforestation for farming, urbanization, continues cropping and overgrazing). Farming in the Northern Ghana is also adversely affected by insufficient rainfall, high cost of inputs and striga infestation. Crop yields are on decline on smallholder farmers' fields and there is a huge gap between potential and the actual crop yields (Yeboah *et al.* 2009). This has led to low income and food insecurity in the region. Estimates show that approximately 80 % of the population in the northern savannah zone is poor (Ekekpi and Kombiok, 2008) and engaged in subsistence agriculture.

According to Sahrawat *et al.* (2001), to effectively reverse the trend of declining productivity we require soil fertility replenishment. Thus, the promotion of soil and water conservation (SWC) technologies has been suggested as a key adaptation strategy for countries in the developing world, particularly in sub- Saharan Africa, to mitigate growing water shortages, worsening soil conditions, and drought and desertification (Kurukulasuriya and Rosenthal, 2003). In view of this, the Challenge Program on Water and Food (CPWF) in 2006 undertook a project in Northern Ghana that focused on developing and implementing selected soil and water technologies, such as: fertilizer micro dosing, which is strategic application of fertilizers, Savannah Eco-farm, an integrated soil-water-plant- nutrient management and combination of rainwater and nutrient management and soil degradation control. These techniques were tested on-farm on some selected farmlands in Northern and Upper East Region of Ghana. This study was carried out with the aim of helping small scale farmers in improving soil fertility. Soil fertility in Ghana is often associated with soil organic carbon content, because of the low use of mineral fertilizers and it also depends on biomass managements and inputs, mineralization, leaching and erosion (Nandwa, 2001).

1.2 Problem Statement and Justification

Soil fertility decline is a major problem confronting crop production in Ghana especially in the northern ecological zone. This is caused by crop nutrient removal and losses through soil erosion. As a result, most of the soils are poor in the essential plant nutrients required. This leads to low crop yield. In view of this the 'Challenge Program of Water and Food ' CPWF was part of the CGIAR research program on Water, Land and Ecosystems, implemented in 2008 in some selected communities of Northern and Upper East Regions of Ghana to help resource poor farmers to employ various soil and water conservation techniques, such as:

- fertilizer micro dosing, which is strategic application of fertilizers;
- savannah eco-farm, an integrated soil-water-plant- nutrient management, soil fertility management and Striga control strategy and;
- combination of rainwater and nutrient management and soil degradation control

These techniques were tested on-farm.

Soil conservation is usually carried out to avoid or reverse erosion and other forms of soil degradation. It involves the application of measures to restore degraded soils and prevent them from further damage, and adopting sound soil management methods that yield sustained satisfactory crop production (Quansah, 2000). These techniques, when adopted by farmers, were expected to improve soil fertility and improve yields with consequential effect on poverty and food security of beneficiary farmer's households. Since the introduction of the project in 2008, there had not been any follow-up research to assess the soil nutrients status, rate of erosion and effects of the techniques on farmers' soil physical and chemical properties. This study therefore assesses the effect of the programme on farmers' fields based on some selected physical and chemical properties on participant and non-participant farms to give insight of the effects of the challenge programme on farmers' livelihood. This research thus provides an assessment of the programme for project implementers and other stakeholders and could form the basis for up scaling the programme to other areas.

1.3 Objectives of the Study

The main objective of the study was to determine effects of soil and water conservation techniques on physical and chemical properties of soil in the savannah ecological zone on some selected farmer's fields, and compare these with changes created as a result of the CPWF project.

The specific objectives considered were;

1. To compare the chemical properties of the soil such as soil organic matter (SOM), organic carbon (OC), carbon accumulation (Cc), total nitrogen (N), potassium (K), phosphorus (P), cation exchange capacity (CEC) in the five (5) selected participant bench mark sites and compare it with non-participant and to the baseline or pre data from CPWF in 2006.
2. To compare physical properties of the soil such as bulk density, porosity, soil moisture content and infiltration on the participant and non-participant bench mark sites.
3. To estimate and compare erosivity index for prediction of erosion occurrence for the selected study area.

1.4 Hypothesis

1. H_0: The SWCT did not improve the physical properties of participant farmer's field

H_A: The SWCT significantly increased the physical properties of participant farmer's field

2. H_0: The SOM, OC, Cc, N, K, P, CEC in participant bench mark sites are not significantly higher than non-participant bench mark sites

   H_A: The SOM, OC, and Cc, N, K, P, CEC in participant bench mark sites are significantly higher than non-participant bench mark sites

3. H_0: The bulk density, porosity, soil moisture content and infiltration on the participant and non-participant bench mark sites are the same

   H_A: The bulk density, porosity, soil moisture content and infiltration on the participant bench mark sites are significantly different than non-participant bench mark sites

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature on the characteristics of soils in the savannah zone, soil nutrient status in terms of physical and chemical properties globally, and in the northern sector of Ghana, gives an overview of loss of soil favourable natural properties as a result of land use and land management, continuous cropping, nutrient mining; problems of the soils in the savannah ecological zone as a result of soil erosion and degradation, runoff and other related causes of low soil productivity.

2.2 Impacts of Soil and Water Technologies on Small Scale Farms

Improving soil fertility, water harvesting, enhancing the soil-water retention capacity and reducing soil erosion are measures that could significantly improve agricultural productivity in rainfed environments. Thus, soil and water conservation practices are becoming increasingly important in the arid and semi-arid farming systems. Appropriate and site specific technologies are needed to address poverty and food insecurity. Both available scientific knowledge and indigenous knowledge by communities should effectively contribute to this process and farmers should actively participate in the design, implementation, and evaluation as well as in the dissemination of such technologies (Duveskog *et al.* 2003). Some of the soil and water technologies practiced commonly by farmers are discussed below.

2.2.1 Mulching

Mulching is done by covering the soil between crop rows or around trees or vegetables with cut grass, crop residues, straw or other plant material (Schonbeck, 2012). This practice helps to retain soil moisture by limiting evaporation, prevents weed growth and enhances soil structure. It is commonly used in areas which are subject to drought and weed infestation. The mulch layer is rougher than the surface of the soil and thus inhibits runoff. The layer of plant material protects the soil from splash erosion and limits the formation of crust. The optimal proportion of soil cover ranges between 30 % and 70 % (Duveskog *et al.* 2003). Research work done in Ghana so far shows mulching and ridging across slope as an important soil and water conservative measures which could be live or dry mulch using cover crop or crop residue. Crop residue left on the soil surface is important in preventing crust, increasing organic matter content of the soil, improving its tilth and increasing infiltration (Lal, 1976).

2.2.2 Composting

Composting attempts to create the conditions which will occur in undisturbed ecosystem, where organic matter builds up on the soil surface and is not regularly incorporated into the soil as in agricultural ecosystems (Lampkin, 1994). Most nutrient contents of compost, especially those derived from farmyard waste; vary considerably, depending on type of raw materials used, method of composting and maturity. According to Hadas *et al.* (1996), nutrients in compost are generally less available, compared to manures or leguminous cover crops. Churchill *et al.* (1996) reported that the major aim for reduced nutrient availability in composts is greater degree of decomposition, leading to the production of humic substances, resulting in a slower release of nutrients.

2.2.3 Crop Rotation and Intercropping

Kombiok *et al.* (2012) indicated that cereal production in Ghana, especially northern Ghana, is limited by low levels of nitrogen in the soil. Strategies such as intercropping, mixed cropping and crop rotations involving cereals and legumes, have been adopted to raise crop yields as they fix substantial amounts of atmospheric N, can provide large amounts of N-rich biomass.

Intercropping systems, including different kinds of annual crops planted in alternating rows, also reduce soil erosion risk by providing better canopy cover than sole crops (Morgan, 1995). Carsky *et al.* (2001) worked on cowpea-cereal rotation systems in northern Nigeria and found that grain yields of the leguminous crop planted in the early season were relatively high (400 to 700 kg ha^{-1}), since insect pressure and pest damages were reduced. The grain yields of maize planted in the second part of the same season were higher after the cultivation of legumes than after a grass fallow, due to the additional nitrogen supply. The authors concluded that intercropping of early maturing cowpea varieties with maize can be a relatively productive low input system for the Guinea savanna. Legumes grown as a food crop or live mulch can be successfully rotated with a crop which produces high biomass or intercropped with tree species (alley cropping) in order to provide N, enhance organic matter content and agroforestry. In the northern savanna zone, however, the cover crop dries when the rains end in October and the residue forms mulch protecting the soil. The incorporation of the residue in the soil after two years of cropping increased both the soil nitrogen and maize grain yield significantly (Kombiok and Clottey, 2003). The amount of N returned from legume rotations depends on whether the legume is harvested for seed, used for forage, or incorporated as a green manure. Rotations allow crops with different rooting patterns to use the soil sequentially reduce pests and diseases harmful to crops and sustain the productivity of the cropping system. These crops have the advantage over other legumes in that they provide a direct economic yield for food or for sale (Kombiok *et al.* 2012). In northern Ghana, where farmers indicated their normal rotation is cereal/legume, data showed that the actual area sown to the legume was often less than 30 % of the farm area. Odunze *et al.* (2004) determined the effect of grain legumes in legume/cereal treatments on soil properties in the arid ecosystem of northern Nigeria. The results showed that sole groundnut improved the soils' bulk density at the 0 to 10 cm depth (1.26 $g\,cm^{-3}$) more than sole maize crop cultivation (1.34 $g\,cm^{-3}$). The cultivation of legumes also resulted in better stability of soil aggregates in the topsoil, which generally reduces the erodibility of the soil. Investigations on the effect of intercropped root and tuber crops with cereals on soil properties were conducted by Ghuman and Lal (1991). They measured moisture content of 14.5 % to 14.7 % in the top 20 cm of plots with maize, melon, and yam and from 12.7 % to 14.2 % on monocropped maize plots. Pigeon pea is an ideal legume for intercropping with cereals. Its slow initial growth affords little competition with the cereal for light or water, and it continues growing into the dry season after the maize crop has been harvested. The leaves that fall from pigeon pea before harvest provide a mulch and can add as much as 90 kg N/ha to the soil that then mineralizes relatively slowly during the subsequent season, releasing N for the next maize crop (Adu-Gyamfi *et al.* 2007). Thus, a substantial rotational benefit, although not a perfect soil cover, can be achieved for the next season.

2.2.4 Minimum Tillage and No-til

Morgan (1995) describes minimum tillage - a practice where soil preparation is reduced to the minimum necessary for crop production and where 15 % to 25 % of residues remain on the soil surface. No-till or zero-tillage is characterized by the elimination of all mechanical seed bed preparation, except for the opening of a narrow strip or hole in the ground for seed placement. The surface of the soil is covered by crop residue mulch (Lal, 1983). Tied ridging or furrow diking includes the construction of additional cross-ties in the furrows between neighbouring contour ridges (Lal, 1990). The fact that the soil is not tilled and remains permanently covered with crop residues leads to efficient erosion control, sequestration of atmospheric carbon in the soil, increased biological activity in the soil, better conservation of water and higher economic returns over time (Derpsch, 2010). A review of tillage studies in Nigeria Opara-Nadi (1990) shows that no-tillage with residue mulch is appropriate for Luvisols in the humid tropics. No-tillage is used in mechanized wheat farming in northern Tanzania and for some perennial crops, for example coffee plantations (Antapa and Angen, 1990). Several studies (Smika and Unger 1986; Unger *et al.* 1988; Parr *et al.* 1990) have reported the success of no-tillage systems in many parts of the USA. Though the use of no-till is increasing, adoption has been slow. Parr *et al.* (1990) report that in the USA, no-till is practiced on less than 10 % of the farmland that is in some form of conservation tillage. No-till fallow is a type of no-tillage system which is used in the dryland areas in the USA. No-till fallow has been most successful in summer rainfall areas (Parr *et al.* 1990). According to Parr *et al.* (1990), the potential benefits of no-till fallow, compared with other tillage systems, are more effective control of soil erosion, increased water storage, lower energy costs per unit of production and higher grain yields. Several studies showed that reduced and zero-tillage systems contribute to long-term maintenance of the soil structure, as pores from root growth and the activity of the soil fauna and the soil aggregates from the previous years are less or not at all disturbed (Lal 1993; Franzen *et al.* 1994). Onwualu and Anazodo (1989) mentioned a higher porosity of soils under conventional treatments (52.9 %) than under no-till (40.3 %) as tillage loosens the soil. But the larger pore volume of tilled soils is only temporary and collapses rapidly under the impact of rainfall and runoff during the rainy season. Soils with reduced tillage are characterized by less total pore space, but have more stable fine pores and fewer air-filled pores than tilled farmland soils (Osunbitan *et al.* 2005). Studies on the bulk density of surface soil layers showed differences according to the tillage methods. Changes in the bulk density of no-till treatments with mulch during the year were negligible, according to Ogunremi and Lal (1986). Comparable results were observed by Aina *et al.* (1991) and Kayombo and Lal (1993). Studies on the influence of different tillage methodologies on the soil moisture content were made by Lal

(1976, 1986), Ojeniyi (1986), Opara-Nadi and Lal (1987), and Amezquita *et al.* (1993). They all recorded that the moisture content was higher in the surface soil of no-till plots, than in treatments prepared with tillage machines. The more favorable moisture and temperature conditions in plots with reduced or no tillage also have beneficial effects on the activity of the soil fauna, such as earthworms. These soil organisms reduce compaction and crust formation, construct macro pores, and contribute to an improved soil structure by the formation of stable aggregates. These processes improve the infiltration rate for rainwater and reduce the erodibility and, hence, the erosion of the soil (Lal 1982; Aina *et al.* 1991). In addition, the content of organic carbon and nitrogen was maintained at significant higher levels in the surface soil of untilled systems than in tilled systems. The maintenance or increase of the organic matter by conservation tillage is a basic ingredient in maintaining soil productivity and the stability of systems according to Lal (1982). Investigations on the impact of different tillage operations on crop yields are numerous and were conducted by Hulugalle *et al.* (1985), Maurya (1986, 1988), Oni and Adeoti (1988), Lal (1978, 1995, 1997), Olaoye (2002), and Anikwe *et al.* (2007). Eziakor (1990) recommends ridge tillage also for shallow soils, where hardpan seriously restricts root development and crop production. The accumulation of soil material increases the rooting zone and the mixture of the topsoil with nutrients and moisture from the subsoil facilitates the growth of crops. In addition, the burning of the vegetation before planting of crops by farmers has been discouraged since the discovery of the full benefits of mulch, which include improved moisture infiltration to reduce soil erosion, will not be realized in such a situation (Wagger and Denton, 1992). Juo *et al.* (2003) recommended that strategies for maintaining soil organic matter are: use of minimum tillage for seedbed preparation and weed control; return of crop residues to the soil as mulch; use of compost, manures, household, and municipal wastes to replenish nutrients and provide new organic matter. Bonsu and Obeng

(1979) showed that mulching is the most effective way of conserving soil, as it results in the least soil loss compared to the other methods such as no-tillage, minimum tillage, ridging across slope and mixed cropping. Also, in the Guinea savannah zone on a 2 % slope, Bonsu *et al.* (1996) showed that mulching is comparatively better in terms of soil loss compared to other methods. In both studies, it was observed that repeated application of soil conservation practices resulted in declining soil loss.

2.2.5 Cover Cropping

According to Lal (1995), cover crops, such as the legumes (*Pueraria phaseoloides, Mucuna pruriens, Centrosema pubescens, Stylosanthes guianensis,* and *Phaseolus aconitifolius)* or the grasses (*Pennisetum purpureum, Brachiaria ruziziensis,* and *Paspa lumnotatum)* are plants that grow rapidly and close. Cover crops have been studied for controlling weed and as mulch for improving soil organic matter. In the past, Mucuna (*Mucuna pruriens*) (Boateng, 1997) .Other cover and leguminous crops have been studied (Fosu *et al.* 2001; Agyare *et al.* 2002). Cover crops clearly influence physical soil properties such as the infiltration rate, moisture content, and bulk density (Hulugalle *et al.* 1986). They increase the organic matter content, nitrogen (N) levels by the use of N_2-fixing legumes, the cation exchange capacity and hence, crop yields (Ile *et al.* 1996; Ibewiro *et al.* 2000; Salako and Tian 2003). Most of the cover crops being promoted as materials for soil fertility improvement are not edible and so farmers are not very enthusiastic in adopting them for use. Most farmers therefore choose grain legumes among the range of soil fertility management practices due to the immediate provision of food (Chikowo *et al.* 2004; Adjei-Nsiah *et al.* 2007; Kerr *et al.* 2007; Ojiem *et al.* 2007).

2.2.6 Alley Cropping and Agroforestry

Agroforestry is a collective name for a land use system in which woody perennials are integrated with crops and/or animals on the same land management unit. The integration can be either in a spatial mixture or in a temporal sequence (Rudebjer *et al.* 2001). Research done on alley cropping with leguminous trees or shrubs establishes focus on improving soil fertility management. Raintree (1980), Kang and Mulongoy (1987), Hauser (1990), Kang (1993a), Mulongoy *et al.* (1993), and Kang *et al.* (1995) investigated nutrient recycling and stated that hedgerows induce a spatial soil chemical micro variability within the alley cropped plots. Research on nitrogen in alley cropping systems were made by Sanginga *et al.* (1989), Okogun *et al.* (2000), and Vanlauwe *et al.* (1996, 2001, 2005). Smucker *et al.* (1995) indicated that *Leucaena leucocephala* competed with the first two rows of the alley cropped maize and cowpea. Analyses made by Kang *et al.* (1985) showed that alley cropping has beneficial effects on the faunal activity and the soil moisture content that is maintained or increased by pruning. Lal (1989) also measured a significant improvement of the available water capacity by *Leucaena leucocephala* (42 %) and *Gliricidia sepium*-based systems (56 %) compared to no-till system. Alley cropping has been regarded as a promising methodology for soil fertility management in the tropics as the regular adding of pruned plant material enhances the organic matter content of the soil (Kwesiga *et al.* 2003). On-station and on-farm trials conducted by Mulongoy *et al.* (1993) showed that treatments with *Leucaena leucocephala* maintained the organic carbon in the same level (1.64 %) as the bush regrowth (1.63 %) in some fields. However, Iwuafor and Kumar (1995) did not find any significant effect of *Leucaena leucocephala* pruning on organic carbon, and Lal (1989) and Diels *et al.* (2004) observed that soil organic matter in alley cropping systems declined with duration of cultivation. Kombiok *et al.* (2012) indicated that alley cropping is not widely practiced in Ghana, but it is found in few places in the southern part of Ghana. The author further reported that, similar to agro-forestry systems, fast growing shrubs or trees such as pigeon pea are planted in alleys, while cover crops such as *Mucuna or Calapogonium spp* are planted to protect the soil from erosion and for weed control. Trees drastically help to reduce the fallow period by fixing nitrogen and providing nutrient rich biomass to restore organic matter and improve soil beneath them which invariably would contribute substantially in improving yields on small scale farmer's fields (Angima *et al.* 2002).

2.2.7 Structural Barriers

According to Morgan (1995), structural barriers made of stones or vegetation installed along contour lines is mechanical erosion control measure. As they operate as filters, they may not reduce the runoff amount, but retard its velocity and hence encourage sedimentation, increase infiltration, and facilitate the formation of natural terraces (Lal, 1990). Vegetative barriers are usually constructed as single lines or in the form of strips several meters wide. Malgwi (1992, 1995) investigated the effectiveness of vetiver (*Vetiver zizanioides*), a perennial grass with a deep and fibrous root system, in northern Nigeria. Records on on-farm trials with vetiver in the derived savanna were also made by Kolade (2006), who emphasized the beneficial effects on soil conservation and economic advantages. Lal (1995) published a list of grass species commonly used for establishing vegetative hedges in the humid tropics and stated the thick root systems prevent riling, gullying, and tunnelling. References on the use of stone lines installed as barriers on the field were not found in this study. In general, mechanical measures are effective soil conservation technologies as they reduce soil loss. But as the installation and maintenance is usually labour-intensive, these structures are not likely to be adopted by farmers. In stony areas, mostly in the Upper East Region of the country, stone bunds are built to trap soil and water for crop production. The stones are lined along contours to form a stone bund or arranged to create a terrace (Antwi *et al.* 1998).

2.3 Soil fertility Level of Tropical Soils

Soil fertility decline is known as a form of degradation, it is prevalent on smallholder farms that are continuously cultivated. In farmers' fields, fertility drop occurs if crop uptake is not compensated for with tolerable nutrient amendments through the application of fertilizers or return of much needed organic matter from plant debris or most importantly, the use of agroforestry technology that could subsidize substantial amounts of nutrients to the soil (Gaisie, 2011).

Many African soils show nutrient deficiency problems after only a short period of cultivation because of their nature as well as prevailing environmental conditions. Farmers have sought to furnish additional nutrient by the application of compost, manures and chemical fertilizer so that the yields of crops will no longer be limited by the amount of plant nutrients that the natural systems can supply (Padwick, 1983). According to (Cook and Ellis, 1987), organic matter additions are the only means of making some soils economically productive. Among the practices recommended for improvement of the soil quality and soil fertility in tropical regions is the application of composted organic wastes, which slowly release significant amounts of nitrogen and phosphorus (Muse, 1993; Zibilske, 1987; Eghgall, 2001). The combination of heavy macronutrient fertilization with intensive production common to conventional farming may lead to micronutrient deficiencies (Brady and Weil, 2002). The use of mineral fertilizer alone has however not been helpful under intensive agriculture because it is often associated with reduced yield, soil acidity and nutrient imbalance (Ayoola, 2006).

Nutrient needs and fertilizer recommendations are based on the nutrient supplying capability of the soil and the additional nutrient needed by crops to achieve their potential yields. The amount of nitrogen, phosphorus and potassium (NPK) required by most crops to achieve long term economic yields in Ghana is arrived at after soil testing, a requirement prior to the application of fertilizers to determine the suitability of soil pH and availability of P and K. It can also disclose whether addition of limestone, P or K is required for optimum productivity (Gaisie, 2011).

2.4 Soil Fertility Levels of Soils in Northern Ghana

Generally, the Sudan Savanna Ecological Zone is mostly underlain by ingenious and metamorphic rock of pre-cambrian age. According to (Kranjac-Berisalvjevic *et al.* 1999) rock in northern Ghana consists of granite and the group of metamorphic rocks referred to as the brimian, which is the oldest in the region consisting of schist phyllites sheared conglomerates, quartzite and metavolcanic rocks.

Quansah *et al.* (1997) indicated that the selective removal of fine soil particles that is high in soil fertility constituents leads to loss of soil fertility.

2.5 Soil Physical Properties

The physical properties of a soil are the result of soil parent materials being acted upon by climatic factors (such as rainfall and temperature), and being affected by relief (slope and direction or aspect), and vegetation, with time (Brady and Weils, 2002). A change in any of these soil-forming factors usually results in a difference in the physical properties of the resulting soil.

2.5.1 Soil Bulk Density

According to (White, 2006) bulk density is the mass of oven-dry soil per unit volume, and depends on the densities of the constituent soil particles and other packing and arrangement into peds. Eldor

(2007) further define bulk density of a soil as the mass per unit volume of soil consisting of solid and gas phase.

According USDA National Resources Conservation Services (NRCS, 2006), bulk density is an indicator of soil compaction. Crop rotations reduce bulk density and increase aggregate stability in contrast to monocrops (Karlen *et al.* 2006). According to Juo *et al.* (2003), oxidic soils are strongly weathered red and yellowish, fine textured, contain more Fe than Kaolinitic soils, and typically have a low bulk density. Allophanic soils are dark-colored young soils derived mainly from volcanic ash and have a low bulk density.

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. Obi and Ebo (1995) reported that stability soil structure is enhanced thereby reducing soil bulk density and increasing porosity. Lombin (1999) reports that the physical characteristics of soil are closely linked with the development of crop root. Lower bulk density enhances aeration and reduces mechanical resistances to root penetration. Bulk density of tropical soil above which root fails to penetrate soils are 1.75 g/cm^3 for sandy soil, 1.46-1.63 g/cm^3 for clayey soil and an average of 1.50-1.70 g/cm^3 for most of the soil range. There is a tendency for bulk density to rise with depth as effect of cultivation and organic matter decrease. The compacted subsoil of whatever texture may have bulk densities exceeding 2 g/cm^3. Armon (1980) found out that bulk density of the surface (0 to 5 cm) layer was significantly higher in conventionally tilled plots (1.35 g /cm^3) than in no-till plots (1.16 g/cm^3) before plowing and planting. Bulk density was reduced due to the loosening effect of tillage and increased again later as a result of the gradual compaction of soil particles resettling after soil preparation (Onwualu and Anazodo 1989).

2.5.2 Soil Porosity

Soil porosity is the proportion of volume occupied by air and water and is determined largely by arrangement of the solid particles. Porosity is the percentage volume of pore space (Ellis and Mellor, 1995). Soil porosity is part of the property structure known as soil structure which includes the arrangement of particles in aggregates, and the size, shape and distribution of the pores both within and between the aggregates. If the particles lie close together as in sandy soils or compacted subsoil, the total porosity is low. If they are arranged in porous aggregates, as is often the case in medium-textured soil high in organic matter, the pores spaces per unit volume will be high (Brady and Weil, 1999).

Porosity depends on the water content of the soil, since the volume of pores and the total volume of an initially dry soil may change differently due to swelling as clay surface hydrates or sinks as the soil dries (White, 2006).

The most rapid water and air movement is in sandy soil and strongly aggregates act like sand grain and packed to form many large pores (Donahue *et al.* 1990). Flurry (1994) reported that a reasonable percentage pore space in a well-drained soil enhances movements of fertilizers and pesticides application in the soil.

Taffa (2002) reported that the soils with small pores have capacity to retain more water to make them available to the crops planted in them. The factors that influence the total pore space in the soil includes the depth of the soil, continuous cropping and size of pore spaces, the water retention capacity and infiltration rate depend on the size and distribution of pore spaces in the soil (Donahue *et al.* 1990). A greater total pore space indicates a greater overall water-holding capacity of the soil (Nyle and Ray, 1999).

Kachinski (1970) gave the following scale of values of porosity of tropical soils. The best soils have porosity to be greater than 50 %; good soils 45-50 %, satisfactory soil 40-44 % unsatisfactory soils under 40 % and poor soil 30 %. Lombin (1999) indicated that an average porosity to be 42 %, loosed structures and compacted tropical soils have a porosity 40 %. Hillel (1982) reported that the values of porosity lie in the range of 30-60 % and observed that coarse textured soils are less porous than fine textured soils. In clay soil, porosity varies due to shrinking, alternate swelling and dispersion.

2.5.3 Infiltration Measurements

Lal (1990) defined infiltration as the downward entry of water from the surface into soil profile. As a key to soil and water conservation, it determines the amount of runoff over the soil surface during rainstorms. Uquatan *et al.*(2011)indicated that when soils are impoverished, or have excessive increase in volume or amount of water that percolates through the horizons, the danger it poses is not only the interference with soil moisture content, but in the enhancement or cascade of plant nutrients and consequently, creating unfavourable condition for sustainable crop production. Infiltration problem may be misread for lack of acceptable soil nutrient a situation that usually accounts for unguided use of agrochemicals to facilitate crop growth and development (Popov *et al.* 2005; Hartemink, 2006). The use of organic and inorganic fertilizers to remedy this condition was experimented (Turk *et al.* 2006; Riley *et al.* 2008). Low values of the infiltration characteristics indicate a possibly high runoff on such slopes (Ogban *et al.* 2000). Presley (2011) stated that infiltration is usually high at first, decreasing gradually, eventually reaching a steady-state of slow infiltration as the soil profile fills with moisture when rain falls. No-till soils usually have a higher infiltration rate than tilled soils at the start of the rain event. But at steady-state, the infiltration rate of no-till soils is often the same as tilled soils. In addition, tillage breaks down the soil structure and decreases initial infiltration rates throughout the soil profile. Raindrop impacts also break down aggregates during a rain event. Soils that are not tilled gain some benefit from slightly higher levels of organic matter, and from the much greater stability of aggregates. According to Ibrahim and Gaheen (1999) the application of composts caused marked changes on soil water infiltration rate. Application of organic waste improved soil hydrologic properties, like infiltration rate and hydraulic conductivity (Diana *et al.* 2008). Mubarak *et al.* (2009) reported that there was a decrease in water movement in sandy soils amended with organic residues.

Table 2. 1: Description of Infiltration Categories

Class	Infiltration Category	Basic Infiltration (cm/h)
1	Very slow	<0.1
2	Slow	0.1-0.5
3	Moderate slow	0.5-2.0
4	Moderate	2.0-6.0
5	Moderate rapid	6.0-12.5
6	Rapid	12.5-25
7	Very rapid	>25.0

Source: FAO (1963)

According to Lal and Shukle (2004), infiltration is the entry of water into the soil matric through the air-soil interphase. The rate of infiltration determines how much water will enter the root zone and how much, if any, will runoff (Hillel, 2004).

Infiltration is not constant over time but generally decrease during an irrigation and rainfall period. If the soil is dry when infiltration begins all the macro pores open to the surface will be available to conduct water into the soil (Lowery *et al.* 1996). The rate of infiltration is the maximum velocity at which water enters the soil surface. When the soil is in good condition, it has stable structure and continuous pores to the surface. This allows water from rainfall to enter unimpeded throughout a rainfall event. A low rate of infiltration is often produced by surface seals resulting from weakened structure and clogged or discontinuous pores (NRCS, 2006)

Proper management of soil can maximize infiltration and capture as much water as allowed by a specific soil type. If water infiltration is restricted or blocked, water does not enter the soil or it either pond on the surface or runs off the land. Thus less water is stored in the soil profile for use by plants. Runoff can carry soil particles and surface applied fertilizers and pesticides off the field. These materials can end up in streams and lakes or in other places where they are not wanted. Furthermore, infiltration acts like a filter which removes some contaminants the water might contain (Khoury-Nolde, 2008).

A dry soil will have a higher infiltration rate than a soil with high water content (USDA, 1998). A fully saturated soil could therefore be considered as an impermeably layer. The presence of vegetation increases infiltration by making the soil more porous due to the movement of roots in the soil (USDA, 1998). An increased amount of parent material, dead or alive, generally assists the process of infiltration. Plants life also protects the soil from the pounding forces of direct rainfall which otherwise might break apart soil aggregates resulting in clogging of the open pore spaces at the soil surface and thus reducing its infiltration abilities (Khoury-Nolde, 2008).

2.5.3 Gravimetric Moisture Content

A soil functions as a medium for plant growth in combination with the moisture available. The water present in the soil facilitates many physical, chemical and biological activities of the soil. Water also acts as solvent and transporter of nutrients, as a nutrient itself, agent in photosynthesis process, maintain plants turbidity and acts as agent in weathering of rocks and minerals (Ikisan, 2002). Gravimetric moisture content is the ratio of weight of wet to the weight of oven-dry soil

(Donahue *et al.* 1994). Furthermore, gravimetric moisture content is the direct measurement of soil water content and is therefore the standard method by which all indirect methods are derived (Taffa, 2002).

At given moisture content, water is held much sticking firmly in the clay than in the sand and loam, and also water in the clay is held tightly in the micro-pores that, it cannot be removed by growing plants (Nyle and Ray, 1999). Water movement may there be impeded and may be inadequate for satisfactory root development in the sub-soil (Donahue *et al.* 1994).

2.6 Chemical Properties of Soils

Chemical properties of soils refer to the nature of the chemical changes taking place in the soils. These chemical changes depend upon their chemical compositions and the nature of the inorganic and organic contained in them, which have originated from the gradual decomposition of the sial and organic materials mainly of plant origin (Kolay, 2000). There are many different nutrients in the soil, all having their own specific function for plant growth. Apart from carbon, hydrogen and oxygen, plants need nutrients that can be subdivided into two groups:

- Macro-nutrients: nitrogen(N), phosphorus (P) and potassium (K), calcium (Ca), sodium (Na), magnesium (Mg), and sulphur (S)

- Micro-nutrients (trace elements): iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo) and chlorine (Cl).

The nutrients needed in larger amounts include nitrogen, phosphorus and potassium, and are referred to as primary nutrients elements. These are followed by the other macro-nutrients, calcium, sodium, magnesium, and sulphur (secondary nutrient elements). While the micro-nutrients are needed in small quantities, their presence in the soil is important (Brady and Weil, 2002).

2.7 Soil Primary Nutrients

2.7.1 Nitrogen

N is one of the critical nutrients for crop production and is generally applied in large quantities in form of fertilizer to soils (Kong *et al.* 2008). It encourages vegetative growth and gives the leaves a good green colour (Havelin *et al.* 2005). A good supply of N stimulates root growth and development, as well as the uptake of other nutrients. The main source of nitrogen in unfertilized soils is the soil organic matter, where it is present in the form of organic N. Organic matter is decomposed by nitrate (NO_3^-) which can be taken up by the plant roots. In this form it is highly mobile and in the rainy season nitrogen is easily leached. As a result, soil nitrates show large seasonal variations (Bradshaw and Chadwick, 1980). Measurement of total nitrogen in the soil therefore does not necessarily give a good indication of soil nitrogen that can be taken up by the plant (Gibbon and Pain, 1985). When too much N is applied, excessive vegetative growth occur; the cells of the plant stems become enlarge but relatively weak and the top-heavy plants are prone to lodging with heavy rain or wind.

Bray and Weil, (2008) reported that, an oversupply of N degrades crop quality, resulting in the undesirable colour and flavour. Excessive application of chemical N fertilizers can also result in N losses through leaching, de-nitrification and volatilization under certain conditions (Akoumianakis *et al.* 2011). Plants which cannot obtain enough nitrogen are susceptible to disease and dislodging. A deficiency or excess can drastically affect crop yield (Olaitan *et al.* 1988).

According to IDC (1995), substantial amount of soils N was tied eith the soil organic matter and the soil N value of 1-1.4 mg/kg are acutely deficient which affects plants growth and development. Agyare (2004) indicated that N content in Tamale ranges between 0.03-0.07 mg/kg in the top soil, and is low. Studies conducted in the Sillum Valley of the northern region (woody savanna) of Ghana show that soil total nitrogen content in the upland and lowlands ranged from 0.06 to 0.1 % in the topsoil and 0.01 to 0.07 % in the subsoil (Dedzoe *et al.* 2001). Dedzoe *et al.* (2002) characterized soils in the Kulda – Yarong Valley in the northern region of Ghana (grass savanna) and found soil total nitrogen levels to range from 0.06 to 0.08 % in the topsoil and 0.03 to 0.04% in the subsoil. Senaya *et al.* (2001) also characterized soils in the Kulawuri valley comprising upland and lowland soils. They found total nitrogen levels to range from 0.07 to 0.10 % in the topsoil and 0.04 to 0.07 % in the subsoil. In the study conducted by Fosu (2005) in the Navrongo area (Sudan savanna), total nitrogen levels ranged from 0.05 % to 0.08 % in the top soil and 0.03 % -0.04 % in the sub soil.

2.7.2 Soil Phosphorus (P)

Phosphorus plays an important role in the setting of fruit and seeds. It is present in the soil in three ways: a liable form, a stable form and the mineral reserve. Phosphorus is the powerbroker; the ATP (adenosine triphosphate) molecules releases the energy required for plant growth when it is reduced to ADP (adenosine diphosphate) in the root cells where respiration takes place. P controls root, seed and flower development, as well as the processes of cell division and sugar formation. Phosphorus is usually present in the soil as phosphate, and only partly soluble and not very mobile. Phosphate binds easily with various components of the soil, resulting in iron and aluminium phosphates in acid soils and calcium phosphates in alkaline soils. When bound in these ways, phosphorus becomes less soluble this means that it is less easily released to become available to plants.

Phosphorus in this bound form is referred to as phosphorus in the stable pool. This means that in most soils only a small portion of the phosphorus in the soil that can be easily taken up by plants (the liable pool). Both the stable and the liable pool consist of inorganic and organic forms of P (Wolf *et al.* 1987). The fact that phosphorus is not very mobile also holds for phosphorus added to the soil (Bradshaw and Chadwick, 1980). Olaitan *et al.* (1988) indicated that after nitrogen, phosphorus was probably the most limiting nutrient in most agricultural soils. Deficiency of phosphorus is common in the highly weathered oxisols and ultisols of the tropics notably in savannah area with low organic matter contents. The form of inorganic phosphorus present in soil is usually indicative of its stage of the weathering. Response for savannah soil values ranges from (20-45 g/kg) with most figures varying between 20 and 25 g/kg. Higher values (30-54 g/kg) have been reported for forest soil (Olaitan *et al.* 1988). Available phosphorus contents in soils found in Tamale ranges to deficient to marginal (5.0-7.0 mg/kg) in the top soil (Agyare, 2004). According to Abekoe and Tiessin (1998), P deficiency is widespread in most soils of northern Ghana, and ferruginous nodules contained in some soils in the region stress the deficiency problems because they act as P sinks. Ferruginous nodules are present in many soils in Ghana and constitute a major problem in P nutrition. Buri *et al.* (2001) evaluated soil fertility status of some lowlands in Ghana and reported generally low levels of available P. Studies in parts of Northern, Upper West and Upper East regions show that available P is very low ranging from trace to 6.0 mg Pkg-1soil (Senayah, 1994; Senayah *et al.* 1998; Issaka *et al.* 2004; Dedzoe *et al.* 2002).

The first two forms of soil potassium are considered to be liable and meet the immediate requirements of growing plants, while the last two are considered non-liable and are responsible for long-term supply of potassium to plants (Askegaard *et al.* 2003). At these contents, potassium is usually the most abundant macronutrient in the top 15 cm of soil (Sparks, 1980). Potassium in the soil is mainly concerned with critical soil nutrient level, element replenishment after crop removal, equilibrium with Ca and Mg, and organic matter supply and decomposition. According to Stanley *et al.* (1967) potassium is one of the essential nutrients in plant growth and development. Potassium is an element that influences the uptake of other elements and affects respiration and transpiration of the plant (Fitzpatrick, 1986).

In tropical soils, the total potassium content may be quite low because of the origin of the soils, high rainfall and high temperatures. Unlike N and P, which are immediately deficient in most tropical soils due to leaching and fixation, the need for potassium applications frequently arises only after a few years of cropping a virgin soil. In Ghana, there is usually lack of response to potassium fertilization when soils are brought into cultivation from the fallow state; but even in the more fertile forest soils potassium can be depleted during relatively short intensive cropping periods (Acquaye, 1973). Lack of potassium results in reduction in plants tolerance to drought, increase in lodging and weakens straw in grain crops. Under severe potassium stress, seedling emergence and stand survival problems have resulted lower plant populations at harvest time. Adequate supply of potassium is essential in N uptake, protein synthesis, improves drought tolerance of crops, helps in water transport to maintain plant turbidity, and promotes the formation of carbohydrates and increase the oil content of oil seed crops. Increased application of potassium ion has been shown to enhance photosynthetic rate, plant growth, and yield and drought resistance in different crops under water stress conditions (Egilla *et al.* 2001).

Potassium is the universal helper that flows throughout the plant, regulating osmotic balance, openings and closing of stomata and cell turgor pressure, while stimulating rooting, photosynthesis, chlorophyll formation, starch formation and translocation of sugars. Also adequate potassium levels reduce plant susceptibility to insect and disease attack (ASFG, 2010). Hossner and Juo, (1999) reported that most upland soils in the tropical regions and semi-arid zones are highly weathered and infertile, acidic and thus contain very low level of potassium.

2.8 Other Soil Chemical Properties

2.8.1 Soil Reaction (pH)

Soil pH is the measure of the acidity or the alkalinity of the soil and is sometimes called soil reaction. Soil pH is the foundation of essentially all soil chemistry and nutrient reaction and should be first when evaluating a soil test. The ability of plants to absorb the nutrients from the soil depends on certain soil characteristics such as the soil's acidity (pH), which is not the equivalent for all nutrients. A higher pH may have a positive influence on the availability of one nutrient and a negative influence on another. In view of this, plants differ in their ability to mobilize and utilize nutrients from a given soil (Euroconsult, 1989). The total range of pH scale is from 0-14. The value below the mid-point is acidic and those above pH 7.0 are alkaline. Soil pH of 7.0 is considered to be neutral. At a pH of 7 (neutral), acidity and alkalinity are balanced. Acidity increases by a factor of 10 with each 1-unit drop in pH below 7.0 for example, a pH of 5.5 is ten times as acidic as a pH of 6.5. Alkalinity increases by a factor of 10 with each 1-unit change in pH above 7.0 (Cogger, 2005).

An acid soil can restrict the root and top growth of plants, reduce the availability of plant nutrients, decrease desirable biological activity, and increase the availability of toxic elements in the soil. If soil acidity is not properly managed, full benefit of other expensive and time-consuming soil management practices cannot be realized. Spector (2001) indicated that if the soil pH is too acidic, plants cannot utilize NPK and other nutrients. Lime sufficient to raise pH to about 5.6 or 5.7, reduces exchangeable Al^{3+} to less than 10 % of the cation exchange capacity, and will determine the pH related crop production problems. Crops vary widely in their tolerance to acidic soils.

2.8.2 Soil Exchangeable Cations

Cation exchange capacity (CEC) is an index of the soil's capacity to exchange cations with the soil solution. It affects the ability of the soil to adsorb and retain cations and heavy metals. Cations are held to the soil particles by adsorption and can be returned to the soil solution for plant use by exchange process. Soils that have high CEC and organic soils can exchange and retain large amounts of cations released by agricultural waste mineralization processes. Conversely, soils in which the CEC is low have low potential for exchanging and retaining these agricultural waste materials. The potential for agricultural waste contamination of underlying ground-water and aquifers is highest for soils that have low CEC and lowest for those with high CEC. As recommended by Quirine *et al.* (2007) cations are positively charged ions as potassium (K^+), sodium (Na^+), hydrogen (H^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), iron (Fe^{2+}), manganese (Mn^{2+}), zinc (Zn^{2+}), copper (Cu^{2+}) and Aluminium (Al^{3+}). The CEC of a soil is expressed in cmol/kg (centimol positive charge per kilogram of soil) or meq/100 g (milli-equivalents per 100 grams of soil). Both expressions are numerically identical (10 $cmol^+$ /kg = 10 meq/100kg). The soils ability to retain, store and fix cationic nutrients is its cation exchange capacity. It is influenced by the amount and activity of clay mineralogy, organic matter content and soil reaction (Agyare, 2004).

However, sandy soils low in organic matter have a very low CEC (less than 3 cmol/kg) while heavier clay soils or soils high in organic matter generally have a much higher CEC (greater than

20 cmol/kg). Low CEC soils are more likely to develop potassium and magnesium (and other cation) deficiencies, while CEC soils are susceptible to leaching losses of these cations (Quirine *et al.* 2007). Soil organic matter and clay minerals are the two most important constituents that influence soil CEC. Thus increasing soil organic matter through compost addition is likely to increase CEC. McConnell *et al.* (1993) in a review of composting concluded that applying compost at normal agronomic rates (38 to 75 Mg ha^{-1}) would increase the CEC of most mineral soils used for agriculture by a minimum of 10 %. In general, sandy soils have low colloidal materials; hence low CEC as compared to those by silt-loams and clay-loams. High CECs is associated with humus as compared to those exhibited by inorganic clays, especially kaolinites. The cations on the CEC of the soil particles are easily exchangeable with other cations and as a result, they are made available for plant growth (Quirine *et al.* 2007). The effective cation exchange capacity (CEC) of many savannah soils is low, often below 4 meq/100 g, and is closely related to the organic matter and clay contents of the soils, many of which have a variable charge (Sanchez, 1976).

2.8.3 Organic Carbon Content

Organic matter is the most important source of nitrogen in unfertilized soils (Bradshaw and Chadwick, 1980). ASFG (2010) indicated that organic matter (OM) supplies many plant nutrients and the carbon necessary for the proliferation of all living things. In addition, organic manures increase soil C and N pools by increasing protected SOM within aggregates (Williams, 1999 and Judith *et al.* 2009). The top metre of the world's soils stores approximately 2200 Gt (billion tonnes) of carbon, two-thirds of it in the form of organic matter (Batjes, 1996).

According to Jones (2006), one of Australia's leading experts on carbon sequestration stated that: 'Every tonne of carbon lost from soil adds 3.67 tonnes of carbon dioxide gas to the atmosphere. Conversely, every one tonne increase in soil organic carbon represents 3.67 tonnes of carbon dioxide sequestered from the atmosphere and removed from the greenhouse equation'. "For example, a 1 % increase in organic carbon in the top soil 20 cm of soil with a bulk density of 1.2 g/cm^3 represents a 24 t/ha increases in soil organic carbon which equates to 88 t/ha of carbon dioxide sequestered." Data from the Rodale Institute's long-running comparison of organic and conventional cropping systems confirms that organic methods are far more effective at removing carbon dioxide from the atmosphere and fixing it as beneficial organic matter in the soil (Rodale, 2003). According to the Rodale Institute (2003), "U.S. agriculture as currently practiced emits a total of 1.5 trillion pounds of carbon dioxide annually into the atmosphere. Converting all U.S. cropland to organic would not only wipe out agriculture's massive emission problem. By eliminating energy-costly chemical fertilizers, it would actually give us a net increase in soil carbon of 734 billion pounds." Organic matter binds to minerals, particularly clay particles, a process that further protects carbon (von Lutzow *et al.* 2006). This is more than three times the amount of carbon held in the atmosphere.

However, soils are vulnerable to carbon losses through degradation. They also release greenhouse gases to the atmosphere as a result of accelerated decomposition due to land use change or unsustainable land management practices (Lal, 2010). Carbon stimulates the proliferation of microbes (fungi, bacteria, actinonycetes and algae), earthworms and other beneficial creatures that live in the soil. It is related to moisture, temperature and aeration, physical and chemical properties of the soils as well as bio-turbation (mixing by soil macro fauna), leaching by water and humus stabilization (organo-mineral complexes and aggregates). Research has shown that organic fertilizers provide a gradual N supply for a long period of time, which improves N use efficiency and reduces N leaching losses (Abbasi and Tahir, 2012). Organic carbon improves soil's water holding capacity, aeration and presence of living organisms in the soil which are vital to plant growth and development (Young, 1976). As suggested by Young (1976), tropical crops require an average range of 0.6-1.2 % of carbon content for proper growth and development. An average of 0.5 % of organic carbon content is required by tropical crops (Landon, 1991). Agyare (2004) also reported that the mean organic carbon content of the top soil for Tamale is 0.46 % and 0.38 % for topsoil and subsoil respectively. Contributing to this low carbon content in some soils may be continual removal of plants material for human and animal consumption with relatively little replacement to the land, respiration losses due to high temperature and erosion losses due to high intensity of rains (Brady and Weil, 1996).

2.8.4 Soil Organic Matter

Bunting (1965) showed that organic matter in an agricultural or horticultural soil consist of a wide range of materials-roots and other plant parts, fungi, bacteria and animals, and their excreta, and the plant and animal materials contained in whatever organic manures have been added to the soil. Soil organic matter is a key component of soil fertility (Chantigny, 2003). Decline in soil fertility and productivity due to excessive nutrient exploitation and depletion of organic matter have stimulated the interest in improving overall soil quality by applying organic amendments from different sources (Soumare *et al.* 2003). The application of organic residues and composts, as sources of organic matter and plant nutrients, is a common practice to improve soil physical and chemical properties that ultimately improve soil fertility status and hence reduces the needs for inorganic fertilizers (McAndrews *et al.* 2006 and Hargreaves *et al.* 2008).

Furthermore, the regular use of organic material (compost) is a prerequisite for sustained upland soils with inherent low natural fertility (Schoningh and Wichmann, 1990). As reported by Nyamangara *et al.* (2003), management of soil organic matter by using composted organic waste is the key for sustainable agriculture. Increasing soil organic matter has added benefit of improving soil quality and thereby enhancing long-term sustainability of agriculture (Laird *et al.* 2001). The organisms involved may be alive, dead, or more or less decomposed by other organisms. A recent FAO assessment of organic recycling states that improvement of soil productivity as a whole is expected to contribute about 60 % of the increased food production that is currently needed worldwide (Hauck, 1981). Organic matter acts directly as a source of plant nutrients and indirectly influences the physical and chemical properties. Very importantly organic agriculture can help reverse climate change.

Farming practices, which involves heavy application of chemical fertilizers, may cause depletion of certain nutrients in soil and others would generally accumulate in excess resulting in nutrient imbalance, which affects soil productivity. In achieving sustainability in agricultural production, organic manure and bio-fertilizer play an important role because they possess many desirable soil properties and exert beneficial effect on soil physical, chemical and biological characteristics. The application of organic manures provide more advantages over mineral fertilizer because of improvements in soil structure, aggregate stability, soil nutrient exchange capacity, water holding capacity, soil bulk density, microbial biomass and activity and crop yields (Barzegar *et al.* 2002 and Manna *et al.* 2007). The beneficial effects of organic wastes on soil physical properties as evidence by increased water infiltration, water holding capacity, water content and permeability, soil aggregation and rooting depth, and by decreased soil crusting, bulk density and, runoff and erosion are widely known (USDA, 1957).

According to Das and Puste (2001), organic waste materials like crop residues, well decomposed cow dung, composts and other rural and urban wastes are considered highly useful resources in enhancing soil fertility and also in build-up of soil organic matter. Organic matter decomposition provides plant nutrients in soil, which in turn increases crop productivity.

Organic matter content in the Guinea and Sudan savanna zones of Ghana is generally low with a mean around 1 % in cultivated fields (Adu, 1969, 1975; Fosu *et al.* 2004). Continuous cropping and high temperatures are considered the main contributors to the low organic matter content. The Guinea and Sudan savannas of Ghana have monomodal rainfall with long and severe dry season that exposes the sparse grass vegetation and any remaining crop residues to annual bushfires and overgrazing. Since organic matter is the main determinant of inherent soil fertility, the soils of Guinea and Sudan savannas are poor soils. In studies conducted by Senayah *et al.* (2001) in the Kumawuri Valley in the Northern Region of Ghana covering an area of about 500 ha, the average topsoil organic matter level was 1.2-1.3 %. The subsoil organic matter level had an average value of 0.9 %. Fosu (2005) in a similar study of 600 ha in the Navrongo (Sudan savanna) area of Upper East Region of Ghana found organic matter content of 0.64 – 1.4 % in the top soil. Agyare (2004) characterized soils of the Tamale area (Guinea savanna) and found organic carbon content of 0.35 – 1.03 % in the top soils of 9 soil series encountered. In another study conducted in the Sillum Valley in the northern region of Ghana, Dedzoe *et al.* (2002) found the soil organic matter content to range from 0.4 to 1.1% in the topsoil and 0.4 to 0.7 % in the subsoil. Organic matter content of soils in the Kulda – Yarong valley of the northern region of Ghana were found to range from 1.1 to 1.9 % in the topsoil and about 0.5 to 0.9 % in the subsoil (Dedzoe *et al.* 2002). These values are averages of upper slope to valley bottom soils.

2.9 Effects of Inorganic and Organic Fertilizers on Soils.

All fertilizers supply plants with the nutrients farmer needs to be in superb shape. However, organic and inorganic fertilizers supply nutrients to soil in different way. Organic fertilizers create a healthy environment for the soil over a long period of time, while inorganic fertilizers work much more quickly, but fail to create a sustainable environment. As recommended by Mäder *et al.* (2002)

who conducted a 21-year study in central Europe comparing organic to conventional farming systems, "organically managed soils exhibit greater biological activity than the conventional managed soil." Organic fertilizers are composed of natural ingredients from plants and animals. Inorganic fertilizers on the other hand, are manufactured from minerals or synthetic chemicals. Both organic and inorganic fertilizers supplement the soil and feed plants with nutrients. However, research conducted comparing organic and inorganic fertilizers provide compelling evidence that organic fertilizers bolster soil health over the long term.

According to Abbasi and Tahir (2012), organic fertilizers provide a gradual N supply for a long period of time, which improves N use efficiency and reduces N leaching losses. Organic fertilizers release nutrients slowly, relying on soil organisms to decompose organic matter. A slow-release scenario decreases the risk of nutrient leaching but takes time to supply nutrients to plants. Inorganic fertilizers contain a higher percentage of nutrients and provide them more quickly than inorganic fertilizers. The main advantage that inorganic fertilizers have over organic fertilizers is that they can be used immediately to rescue dying plants. The key disadvantage of inorganic fertilizers is that it costs much higher than the organic fertilizers. The second drawback is the problem of leaching the fertilizer and nutrients getting washed away, is much more prevalent when inorganic fertilizers are used (Kuruvilla *et al.* 2009). This is because in inorganic fertilizers, the nutrients are already in their most basic components. Besides the essential nutrients required by plants, they contain certain compounds and salts which a plant is unable to absorb and hence, are left behind in the soil. With time, these compounds build up in the soil and even change its chemistry. Over usage of inorganic fertilizers can prove to be detrimental for the plants. Too much of it can burn or destroy the plant structures, including the roots, which can hamper the plant's overall development (Marie, 2001).

2.7 Rainfall Distribution

Climate variability affects agro ecology, growing conditions of crops and livestock. Climate variability and change are one of the greatest impediments to the realization of the first Millennium Development Goal of reducing poverty and food insecurity globally, via increased agricultural production in developing countries (Amikuzunu and Donkoh, 2012).

Climatic factors play an important role in determining the production of food crops in the semi-arid regions of Africa. This is a region characterized by a low and highly variable distribution of rainfall both spatially and over time, which constitutes a limiting potential for crop yields (Tesfaye and Walker 2004; Graef *et al.* 2001). The amount of rainfall and its distribution over the year (especially during the farming season) greatly affects the productivity of agriculture in these regions. It determines the types of crops to be grown, the presence or absence of support activities like irrigation and crop yields, as well as influences agricultural calendar. The start of rains marks the start of the main farming season in northern Ghana, as well as most parts of the Guinea savanna and the Sudano-sahelian region of Africa. This is usually considered to be the planting period for some of the main staple crops of the region, such as maize and beans (Stumpf, 1998). This increase in rainfall intensity (implying increase in mean rainfall per rain day) also corresponds well with projections of future climate change for the region (Kharin *et al.* 2005; Meehl *et al.* 2005; Boko *et al.* 2007). Earlier studies have forecasted these increases in the tropical regions and attributed it to both dynamic and thermodynamic processes associated with global warming (Emori *et al.* 2005). An increase in the intensity of rainfall may also harbour potentially serious risks of an increased flood frequency and severity for most regions of the world (Gordon *et al.* 1992; Fowler *et al.* 1995). While high daily rainfall inputs may be potentially destructive to agriculture in sensitive areas, the destruction caused by rains may sometimes arise from the build-up of several days of rain that fall a little below the utmost rainfall events for that year. This was the situation in the rainy season of 2007, when which exceptionally extensive flooding destroyed fields, homes and granaries and led to the loss of large numbers of livestock in northern Ghana and many areas in the Guinea savanna and Sudano-sahelian agro-ecological zones of Africa (Armah *et al.* 2010; Karley, 2009). This compounded the problem of food shortages and led to unprecedented food price increases. These events were a result of several days of consecutive rainfall below the annual daily maximum rather than a single day of exceptionally high rainfall input.

2.8 Erosivity Index

According to Wischmeier and Smith (1978), rainfall erosive energy indicates the volume of rainfall and runoff, but a long and slow rain may have same erosive energy value as a shorter rain at much higher intensity as erosion increases with intensity (I_{30}), which indicates prolonged-peak rates of detachment and runoff. Therefore, the product term, EI_{30}, combines both total energy and peak intensity. However, most of the other methods mentioned above used total amount of rainfall, therefore, failing to encapsulate intensity component in calculating erosive energy of rainfall. The most suitable expression of the erosivity of rainfall is an index based on the kinetic energy and momentum of runoff. Thus, erosivity index of a rainstorm is a function of its intensity and duration, and of the mass, diameter, and velocity of the raindrops (Morgan, 1995). A number of indices which relate the erosivity of a rainstorm and its associated runoff to soil loss prediction have been established. The most commonly used indices include:

i) AIm index (Lal, 1976)

ii) EI_{30} index (Wischmeier and Smith, 1978; Renard *et al.* 1997)

iii) Modified Fournier Index (Arnoldus, 1980)

iv) KE > 25 index (Hudson, 1995)

The AIm index, EI_{30} index and KE > 25 index are widely used in the tropics. The AIm index is the product of daily rainfall amount and maximum short-term intensity (Im); The EI_{30} index is a product of rainfall kinetic energy (E) and maximum 30-minute intensity, I_{30} and the KE ≥ 25 is a summation of kinetic energy of rainfall exceeding 25 mm hr^{-1}, based on the premise that such rainfall events are the culprits in the soil erosion problem. The Modified Fournier Index (MFI), on the other hand, presents a simple approach. It quantifies the relation between erosive power and energy of using an index based on annual and monthly distribution of rainfall. The MFI ranges proposed by Corine (1992) (cited by Jordán and Bellinfante, 2000), are presented in table 2.2 below:

Table 2. 2: MFI Classification for Rainfall Erosivity

MFI	Description	Class
<60	Very low	1
60-90	Low	2
90-120	Moderate	3
120-160	High	4
>160	Very high	5

CORINE (1992) (cited by Jordán and Bellinfante, 2000)

Several research works done in Ghana has revealed that, Ghana is among countries which are susceptible to soil erosion by water (Quansah, 1990). It is expected that population pressure coupled with the increase in the demand for land for farming and other purposes will intensify soil erosion if soil conservation practices are not implemented. Past studies estimate that 69 % of the total land surface is prone to severe or very severe soil erosion (EPA, 2002) - the main manifestation of land degradation in Ghana. Soil erosion by water and soil degradation in Ghana was noticed way back in the '30s and measures were taken to solve the problem (Quansah, 1990) but nevertheless in 1989 investigations done by the Soil Research institute in Ghana revealed that at least 23 % of the country was subject to very severe sheet and gully erosion, 43.3 % to severe sheet and gully erosion and 29.5 % to slight to moderate sheet erosion. Especially in the Northern part of the country, erosion problems are severe and have intensified due to a combination of factors of both physical and socioeconomic character such as population pressure, poor farming practices, light erosivity, erodibility (Agyepong and Kufogbe, 1994). In the Upper East Region of Ghana for example Adu (1972) reported soil loss of 90 cm of soil by sheet and rill erosion leaving only about 30 cm of corne sandy loam and gravel above the parent materials. But even with some amounts of soil being eroded the higher concentrations of organic matter and plant nutrients in available form found in the eroded material being lost, is having devastating effects on the agricultural production.

2.9 Challenge program on water and food

The CGIAR Challenge Program on Water and Food (CPWF) was an international, multi-institutional research initiative that brought together research scientists, development specialists, and river basin communities in Africa, Asia and Latin America to create and disseminate international public goods and improve the productivity of water in river basins in the manner that was pro-poor, gender equitable and environmentally sustainable. The Challenge Project 5 was funded under the CPWF and had an overall goal of reducing poverty and improving food security, incomes and livelihoods of small-scale resource-poor farmers in the Volta Basin. CPWF (2008) had the objectives of:

- promoting and scaling up best methods of crop, water and nutrient management strategies in the Volta basin through effective information dissemination mechanisms

- to develop and adapt in partnership with farmers integrated technologies that improve water and nutrient use efficiency and increase crop yields in the Volta basin and
- improving the market opportunities for smallholder farmers (CPWF, 2008).

Furthermore, the report revealed that, at Navrongo, poor soils, erratic rainfall and striga infestation where the main problems, while at Tolon, erratic rainfall, soil infertility, and high cost of fertilizer were the constraints of smallholder farmer's farm. To remedy these challenges, the soil and water technologies implemented were minimum tillage, intercropping, tied ridging, stone bunding composting, manure use, cover cropping, alley cropping contour ridging, nutrient use efficient crop varieties and integrated nutrient management.

2.10 Types and Problems Associated with Soils in the Kumbugu District and Kasena Nankani East Municipality

Soils found in the Kumbugu district are predominantly lateritic, and the texture is mainly silt or sandy loam. Their main characteristic is the presence of generally shallow depths below the surface of a more cemented layer of iron pan, through which rainwater does not penetrate easily. It therefore becomes water-logged in the rainy season but dries out completely during the dry season. Soil fertility is a major constraint for agricultural production (Runge-Metzger and Diehl, 1993).

Furthermore in the Kasena Nankani east municipality, two main types of soil are present within the district namely the Savannah ochrosols and groundwater laterite. The northern and eastern parts of the district are covered by the Savannah ochrosols, while the rest of the District has groundwater laterite. The Savannah ochrosols are porous, well drained, loamy, and mildly acidic and interspersed with patches of black or dark-grey clay soils. This soil type is suitable for cultivation and hence accounts for the arable land sites including most parts of the Tono Irrigation Project sites where both wet and dry season farming activities are concentrated. The groundwater laterites are developed mainly over shale and granite and covers approximately 60 % of the District's land area. Due to the underlying rock type (granite), they become waterlogged during the rainy season and dry out during the dry season, thus causing cemented layers of iron-stone (hard pan), which makes cultivation difficult.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Characteristics of the Study Locations

The study was carried out in the Northern and Upper East Regions of Ghana where the SWC programme was implemented. The Kassena Nankana East District lies within the Guinea Savannah woodlands. It is one of the nine (9) districts in the Upper East Region. The District shares boundaries to the North with Burkina Faso, to the East with Bolgatanga Districts, West with the Builsa District and South with West Mamprusi District (in the Northern Region) whiles Tolon district is among twenty-six (26) districts in the Northern Region with Tolon as its administrative capital. The district shares borders with North Gonja to the West, Kumbungu District to the North, Central Gonja to the south and to the East with Tamale Metropolitan as reported by Ghana districts repository 2014.

3.2 Soil Types

In the Upper East Region, the soil belong to the Tanchera association and consist mainly of Puga series (Eutric Plintosol), Tanchera series (Endoeutric-Stagnic Plintosol), Pu Series (Eutric Gleyic Regosol), Kupela series (Eutric Gleysol) and Berenyasi series (Gleyic Arenosol) (Senayah *et al.* 2006). The soils are predominantly loamy sand and sandy loam on the surface.

The soils in the Northern Region were classified as Kumyili series (Ferric Acrisol), Kpelsawgu series (Dystric Plinthosol), Lima series (Eutric Gleysol), Luvisols and Leptosols (Senayah *et al.* 2006). The soils developed over Voltain shales, sandstones and quartz. The texture ranged from clay loam, loam, sandy loam and sandy clays at the surface.

3.3 Natural Vegetation

In both Kumbugu district and Kasena Nankani east municipality, the natural vegetation is savannah woodland, characterised by short scattered drought-resistant trees such as Shea (*Vitellaria paradoxa*), Acacia (Acasia *ablida*), Bauhinia (*Bauhinia thonningi*) and Baobab (*Adansonia digitata*). Neem (*Azadiracta indica*) and Mango (*Magnifera indica*) may be found within and around settlements. Common grasses on cultivated arable land included: *Heteropogon contortus*, *Imperata cylinderica*, *Pennisetum polstachon* and degraded land grasses such as *Dactylon aegyptium, Chloris spp*, *Aristidakerstingii* and *Eragrotis spp*. The grasses dry up during the long dry season and become standing hay for livestock. Human interference with ecology is significant, resulting in near semi-arid conditions in the study location.

3.4 Climatic Conditions

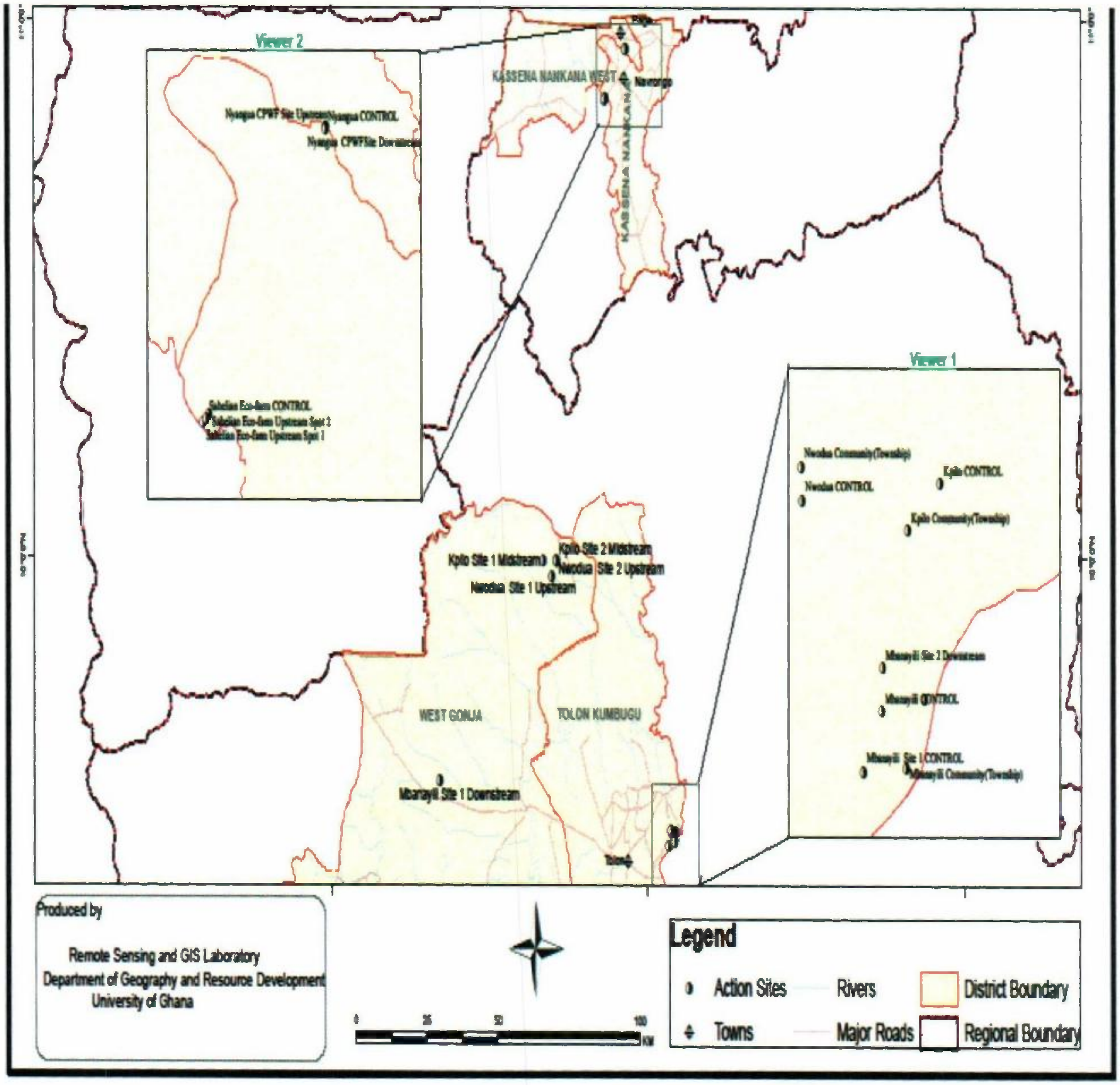
In the Kasena Nankani east municipality, the climate is characterised by unimodal rainy season from May/June to September/October. The mean annual rainfall during this period is between 800 mm and 1100 mm (MoFA, 2012). The rainfall is erratic and there is a long spell of dry season from November to mid-February, characterized by cold, dry and dusty Harmattan winds. Temperatures during this period can be as low as 14 °C at night, but can reach beyond 40 °C during the daytime.

In the Kumbugu district, the climate is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750 mm and 1050 mm (MoFA, 2012). The dry season starts in November and ends in March/April with maximum temperatures occurring towards the end of the dry season (March-April) and minimum temperatures in December and January. The Harmattan winds, which occur during the months of

December to early February, have considerable effect on the temperatures in the region, which may vary between 14°C at night and 35°C during the day.

3.5 Landuse

The various land use forms in the Kasena Nankani east municipality observed during the field visit in 2012 were: cereal-legume rotation, particularly using soybean. Soil moisture management strategies such as tied ridging, minimum tillage, use of drought tolerant crops, nutrient use efficient strategies which are composting and fertilizer micro dosing for the cultivation of sorghum, millet, maize and rice and integrated striga control strategies, and savanna eco-farm which comprises of soil and water conservation technology such as composting and mound with trees such as *Ziziphus mauritiana* (fruit tree) and *Acacia coli* (leguminous tree) as boarders for the cultivation of yam, pepper and maize.



Field studies, (2012)

Figure 3. 1 Map of study locations, showing the Geographical location of Kumbugu and Kasena municipality within Ghana

3.7 Crop Production

Cropping system practiced is continuous cropping and rotation of rice, maize, cowpea and pepper. In the Northern Region, the various land use forms during the field visit in 2012 were strategic placement of small quantities of mineral fertilizer (fertilizer micro dose) for the cultivation of maize, rice, pepper and tomatoes; tied ridging is practiced, as a soil moisture management strategy on-farm to increase rainwater productivity in cereals.

Major crops grown by farmers at Mbanayili, Kpilo and Nwodua are maize, rice sorghum, pepper, groundnut, cowpea, cassava and yam. Farmers in these communities plant on tied ridges, using drought tolerant crops, with minimum tillage, practice of composting and fertilizer micro-dosing. Only farmers in Mbanayili community practiced soil erosion control using the vertiver grass (*Chrysopogin zizanioides*).

At Nyangua in the Kasena Nankani east municipality, farmers cultivate millet, sorghum, maize, rice, pepper and tomatoes. Small scale farmers practice crop rotation, planting of drought tolerant crops, minimum tillage, and fertilizer micro-dosing. At the Eco-farm in Tono, crop rotation and planting of drought tolerant trees were measures practiced by farmers. This was integrated with maize, soya bean, pepper and millet. The Eco-farm was sometimes left fallow for soil nutrient replenishment.

3.8 Data Collection

A reconnaissance visit was undertaken to identify and inspect the studied communities and farmlands in February, 2012. Soil samples were taken from farmlands of both participants of the challenge project and non- participants (Table 3.2, 3.3 and 3.4). A total of one hundred and seventy two (172) soil samples were collected using the core sampler in 2012 and air dried in the laboratory. Primary data on soil physical and chemical properties such as soil types, rate of infiltration, soil and water conservation techniques being practiced by the farmers and types of erosion occurring at the sites were collected in May, 2012 during the rainy season in the field. Secondary data from scientific reports, maps and statistical abstracts were also used as additional sources of information. Data from scientific reports such as journals, annual reports on farmers yield, maps, soil types and rainfall data were also used as additional sources of information and obtained from the Regional office of the Ministry of Food and Agriculture (MoFA), Ghana and Savannah Agricultural Research Institute (SARI) Meteorological Station .

Table 3. 2: Nomenclature of Soil samples and its Description

Samples	Descriptions
P	Participant farm
NP	Non-Participant farm
DS	Downstream
US	Upstream
Ecof	Eco-sahelian farm

Table 3. 2: Geographical Location of the Sampling Points in the Kumbugu District

Site	Nomenclauture	Latitude	Longitude	Altitude(m)
Nwodua	US	N06.99457	W001.28851	153
Nwodua	DS	N06.99457	W001.28851	152
Mbanayili	US	N09.47369	W000.91385	208
Mbanayili	DS	N09.47357	W000.91475	207
Kpilo	US	N06.99457	W001.28851	163
Kpilo	DS	N06.99457	W001.28851	160

Table 3. 3: Geographical Location of the Sampling Points in the Kasena Nankani East Municipality

Site	Nomenclature	Latitude	Longitude	Altitude(m)
Nyangua	US	N10.94781	W001.06857	213
Nyangua	DS	N10.94753	W001.06818	206
Old Tono	Ecof US	N10.84666	W001.14127	183
Old Tono	Ecof DS	N10.84641	W001.14107	178

3.9 Soil / Laboratory Chemical Analysis

The following methods were used to determine levels of various parameters in the soil samples.

3.9.1 Soil Reaction (pH)

Procedure

- The lumps or aggregates were crushed in a mortar and passed through a 2 mm sieve. Soil pH was determined using the glass electrode HT 9017 pH meter in a 1: 2 soil to distilled water (soil: water) ratio (IITA, 1982).
- Approximately 25 g of soil was weighed into a 50 ml polythene beaker and 25 ml of distilled water was added to the soil.
- The soil-water solution was stirred thoroughly and allowed to stand for 30 minutes.
- After calibrating the pH meter with buffers of pH 4.01 and 7.00, the pH was read by immersing the electrode into the upper part of the soil solution and the pH value recorded.

3.9.2 Total Nitrogen

Procedure:

- Total nitrogen was determined by the Kjeldal digestion and distillation procedure as described in Soil Laboratory Staff (1984).
- Approximately 0.2 g of soil was weighed into a Kjeldahl digestion flask and 5 ml distilled water added.
- After 30 minutes a tablet of selenium and 5 ml of concentrated H_2SO_4 were added to the soil and the flask placed on a Kjedahl digestion apparatus and heated initially gently and later vigorously for at least 3 hours, then the flask was removed after a clear mixture was obtained and then allowed to cool.
- About 40 ml of distilled water was added to the digested material and transferred into 100 ml distillation tube. 20 ml of NaOH was added to the solution distilled using the Tecator Kjeltec distiller.
- The digested material was distilled for 4 minutes and the distillate received into a flask containing 20 ml of 4 % boric acid (H_3BO_3) prepared with PT5 (bromocresol green) indicator producing approximately 75 ml of the distillate.
- The colour change was from pink to green after distillation, after which the content of the flask was titrated with 0.02M HCl from a burette.
- At the end-point when the solution changed from weak green to pink, the volume of 0.02 M HCl used was recorded and N % calculated.
- A blank distillation and titration was also carried out to take care of traces of nitrogen in the reagents as well as the water.

Calculation:

The percentage nitrogen in the sample was expressed as:

$$\% N = \frac{(M \times (a-b) \times 1.4 \times mcf)}{s} \quad \ldots 3.1$$

Where;

M = concentration of hydrochloric acid sued in titration.

a = volume of hydrochloric acid used in sample titration.

b = volume of hydrochloric acid used in the blank titration.

s = weight of air – dried sample in grams.

mcf = moistur correcting factor $\frac{100+moisture}{100}$ ...3.2

3.9.3 Organic Carbon Content

Procedure:

- Soil organic carbon was determined by the modified Walkley-Black method as described by Nelson and Sommers (1982).
- The procedure involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid.
- After the reaction, the excess dichromate is titrated against ferrous sulphate.
- Approximately 1.0 g of air dried soil was weighted into a clean and dry 250 ml Erlenmeyer flask.
- A reference sample and a blank were included.

- 10 ml 0.1667 M potassium dichromate ($K_2Cr_2O_7$) solution was accurately dispensed into the flask using the custom laboratory dispenser.
- The flask was swirled gently so that the sample was made wet.
- Then using an automatic pipette, 20 ml of concentrated sulphuric acid (H_2SO_4) was dispensed rapidly into the soil suspension and swirled vigorously for 1 minute and allowed to stand on a porcelain sheet for about 30 minutes, after which 100 ml of distilled water was added and mixed well.
- 10 ml of ortho-phosphric acid and 1 ml of diphenylamine indicator was added and titrated by adding 1.0 M ferrous sulphate from a burette until the solution turned dark green at end-point from an initial purple colour.
- About 0.5 ml 0.1667 M $K_2Cr_2O_7$ was added to restore excess $K_2Cr_2O_7$ and titration completed by adding $FeSO_4$ drop-wise to attain a stable end-point.
- The volume of $FeSO_4$ solution used was recorded and % C calculated.

Calculation:

The organic carbon content of soil was calculated as:

$$\% \, O.C = \frac{M \times 0.39 \times mcf \times (V1 - V2)}{s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3.$$

Where; 0.39 is constant

$0.39 = 3 \times 0.001 \times 100 \times 1.3$ ($3 = equivalent\ weight\ of\ carbon$).

1.3 = a compensation factor for the incomplete combustion of the organic carbon.

M = molarity of ferrous sulphate solution.

V_1 = ml of ferrous sulphate solution required for blank

V_2 = ml of ferrous sulphate solution required for sample.

s = weight of air – dry sample in grams.

$$mcf = moisture\ correcting\ factor\ \frac{100 + moisture}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

3.9.4 Soil Organic Matter

Procedure:

- 20 M of HCl was first added to a 10 g of soil in order to eliminate any form of inorganic carbon.
- The soil sample was heated then placed in a ceramic crucible.
- It was heated overnight between 350 – 440 ^{0}C.
- The sample was removed, cooled in a desiccator and weighed.
- The organic matter content of the soil was calculated as
- $TOM = \frac{M1-M2}{M2} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5$

Where;

TOM = Total organic matter

M_1 = Initial weight of the soil sample

M_2 = Final weight of the soil sample after heating.

The value obtained was then multiplied by a factor of 1.724 (1/an Bemmelen) to get the approximate organic content.

Carbon accumulation was also determined. In a few studies, the values were given in terms of % soil organic matter. In such cases concentrations of C_c (g kg^{-1}) were calculated as follows (Guo and Gifford, 2002):

$C_c = 0.58 \times OM\,\% \times 10$ 3.6

3.9.5 Phosphorus (Available Phosphorus)

Procedure

- The readily available acid-soluble forms of phosphorus were extracted with a $HCl:NH_4F$ mixture called the Bray's no. 1 extract as described by Bray and Kurtz (1945) and Olsen and Sommers (1982).
- Approximately 5 g of soil was weighed into 100 ml extraction bottle and 35 ml of extracting solution of Bray's no. 1 (0.03M NH4F in 0.025 M HCl) was added.
- The bottle was placed in a reciprocal shaker and shaken for 10 minutes after which the content was filtered through Whatman no. 42 filter paper.
- The resulting clear solution was collected into a 100 ml volumetric flask.
- An aliquot of about 5 ml of the clear supernatant solution was pipetted into 25 ml test tube and 10 ml colouring reagent (ammonium paramolybdate) was added as well as a pinch of ascorbic acid and then mixed very well.
- The mixture was allowed to stand for 15 minutes to develop a blue colour to its maximum.

- The colour was measured photometrically using a spectronic 21D spectrophotomer at 660 nm wavelengths.
- Available phosphorus was extrapolated from the absorbance read.
- A standard series of 0, 1.2, 2.4, 3.6, 4.8 and 6 mg P/1 was prepared from a 12 mg/I stock solution by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mg P/I in 100 ml volumetric flask and made to volume with distilled water.
- Aliquots of 0, 1, 2, 3, 4, 5 and 6 ml of the 100 mg P/I of the standard solution were put in 100 ml volumetric flasks and made to the 100 ml mark with distilled water.

Calculation

$$P(mg\ kg^{-1}) = \frac{(a-b)\times 35\times 15\times mcf}{s} \quad \ldots\ldots\ldots\ldots\ldots 3.7$$

a = mg/IP in sample extract.

b = mg/IP in blank.

s = weight of air – dry sample in grams.

$$mcf = moisture\ correcting\ factor\ \frac{100 + moisture}{100} \quad \ldots\ldots\ldots\ldots 3.8$$

35 = volume of extracting solution

15= final volume of samples solution.

3.9.6 Available Potassium

Procedure:

- Available potassium was extracted using the Bray's no. 1 solution and determined directly using the Gallenkamp flame analyser.
- Available potassium concentration was determined form the standard curve. Potassium standard solutions were prepared with the following concentrations: 0, 10, 20, 30, and 50 µgK/ml solution.
- The emission values were read on the flame analyser and standard curve obtained by plotting emission values against their respective concentrations.

Calculations:

$$K\ (mg\ kg^{-1}) = \frac{(a-b) \times 35 \times mcf}{s} \quad \ldots\ldots 3.9$$

Where;

a = µgK/ml in sample.

b = µgK/ml in blank.

s = weight of air – dry sample in grams.

35 = volume of extracting solution.

$$mcf = moisture\ correcting\ factor\ \frac{100+moisture}{100} \quad \ldots\ldots 3.10$$

Exchangeable cations

Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were determine in 1.0 N ammonium acetate (NH_4OAc) extract.

3.9.7 Extraction of the Exchangeable Bases

A 5 g soil sample was transferred into a leaching tube and leached with 100 ml of buffered 1.0 N ammonium acetate (NH_4OAc) solution at pH 7.

Calcium

- A 25 ml portion of the extract was transferred to an Erlenmeyer flask. Hydroxylamine hydrochloride (1.0 ml), potassium cyanide (1.0 ml of 2 % solution) and potassium ferrocyanide (1.0 ml 0f 2 %) were added. After a few minutes, 4 ml of 8 M potassium hydroxide and a spatula of murexide indicator were added.
- The solution obtained was titrated with 0.01N EDTA solution to a pure blue colour. The titre value was again recorded.

Calcium and Magnesium

- For the determination of the calcium and magnesium, a 25 ml of the extract was transferred into an Erlenmeyer flask.
- A 1.0 ml portion of hydroxylamine hydrochloride, 1.0 ml of 2.0 percent potassium cynanide buffer (from burette), 1.0 ml of 2.0 per cent potassium ferrocyanide, 10.0 ml ethanolamine buffer and 0.2 ml Eriochrome Black T solution were added.
- The solution was titrated with 0.01N EDTA (ethylene diamine tetraacetic acid) to a pure turquoise blue colour.
- The titre value was recorded.

The titre value for calcium was subtracted from this value to get the titre value for magnesium.

Calculation:

$$\left[\frac{V1 - V2}{V3} \times V4 \times N \times \frac{100}{W}\right] \times mcf \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.11$$

Where

V_1 = volume of EDTA required for sample aliquot titration, ml.

V_2 = volume of EDTA required for blank titration, ml.

V_3 = volume of aliquot taken, ml.

V_4 = total volume of original NH4OAc extracts, ml.

N = normality of EDTA.

W = weight of sample taken in g.

$$mcf = moisture\ correcting\ factor\ \frac{100+moisture}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.12$$

Exchangeable Calcium plus Magnesium (cmol of Ca + Mg kg^{-1} soil).

$$= \left[\frac{V5-V6}{V7} \times V4 \times N \times \frac{100}{W}\right] \times mcf \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.13$$

Where:

V4 = total volume of original NH4oAc extracts, ml

V5 = volume of EDTA required for sample aliquot titration, ml.

V6 = volume of EDTA required for blank titration, ml.

V7 = volume of aliquot taken, ml.

N = normality of EDTA.

W = weight of sample taken in g.

$$mcf = moisture\ correcting\ factor\ \frac{100 + moisture}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.14$$

1 ml 0.01 N EDTA = 0.2004 mg Ca^{2+} = 0.1216 Mg^{2+} ……………………………………….3.15

Potassium and Sodium

- Potassium and sodium in the percolate were determined by flame photometry.
- A saturated series of potassium and sodium were prepared by diluting both 1000 mg/l potassium and sodium solutions to 100 mg/l.
- This was done by taking a 25 ml portion of eacf into one 250 ml volumetric flask and made to volume with water.
- Portions of 0, 5. 10, 15 and 20 ml of the 100 mg/g standard solution were put into 200 ml volumetric flasks respectively.
- One hundred millitres of 1.0 N NH4AOc solution was added to each flask and made to volume with distilled water.
- The standard series obtained was 0, 2.5, 5.0, 7.5, 10.0 mg/l for potassium and sodium.
- Potassium and sodium were measured directly in the percolate by flame photometry at wavelength of 766.5 and 589.0 nm respectively.

Calculations

$$Exchangeable\ K\ (cmol\ kg^{-1}\ soil) = \frac{(a-b) \times 250 \times mcf}{10 \times 39.1 \times s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.16$$

$$Exchangeable\ Na\ (cmol\ .kg^{-1}\ soil) = \frac{(a-b)\times 250\times mcf}{10\times 23\times s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. 3.17$$

Where;

a = mg/lK or Na in the diluted sample percolate.

b = mg/lK or Na in the diluted blank percolate.

s = weight of air – dry sample in grams.

$$mcf = moisture\ correcting\ factor\ \frac{100+moisture}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.18$$

3.10 Determination of Soil Physical Properties

3.10.1 Gravimetric Moisture Content

Procedure:

- The gravimetric methods as described by Gardner (1986) were used to establish initial soil water content for all sites.
- The soil moisture content may be expressed by weight as the ratio of the mass of water present to the dry weight of the soil, or by volume as ratio of volume of water to the total volume of the soil sample.
- To determine any of these ratios for a particular soil sample, the water mass must be determined by drying the soil to constant weight and measuring the soil sample mass after and before drying. The water mass (or weight) is the difference between the weights of the wet and oven dry samples.
- The criterion for a dry soil sample is the soil sample that has been dried to constant weight in oven at temperature between 100 – 110°C (105 °C is typical).

Procedure

- An aluminium tin was weighed and recorded weight as "tare"
- About 10 g of soil sample was placed in the tin and this was recorded as wet soil
- The soil sample was placed in an oven at 105 °C, and dried for 24 hours or overnight.
- Sample was weighed, and recorded as dry soil.
- Samples were returned to the oven and died for several hours, and determine the weight of dry soil.
- Step 5 was repeated until there is no difference between any two consecutive measurements of the weight of dry soil.

Computations

Gravimetric soil water content was then determined by the following equation (Gardner, 1986)

$$\varphi = \frac{(mass\ of\ wet\ soil - mass\ of\ dry\ soil}{mass\ of\ wet\ soil}\ ({}^{g}/{}_{g}) \ldots\ldots 3.19$$

Where

$\varphi = Gravmetric\ Moisture\ Content$

3.10.1 Volumetric Moisture Content

The volumetric water content (v) was determined from the relation:

$$v = \varphi\left(\frac{Pb}{Pw}\right) \ldots\ldots 3.20$$

$$\varphi = \frac{Mw}{Ms} \ldots\ldots 3.21$$

Where

$Pb = Dry\ bulk\ density$

$Pw = Wet\ bulk\ density$

$Mw = Mass\ of\ wet\ sample$

$Ms = Mass\ of\ soilids$

3.10.2 Bulk density

Procedure

- The dry bulk density of the soil samples was determined from soil cores collected from the field with core sampler using the method of 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.

Computation

The oven dried soils were weighed and the bulk densities were calculated using the equation:

$$\rho b = \frac{(M2) - (M1)}{mass\ of\ dry\ soil(M1)} \left(\frac{g}{cm^3}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.22)$$

Where;

$M_2 = mass\ of\ wet\ soil\ before\ oven\ dry$, $M_1 = mass\ of soil\ after\ oven\ drying$

ρb = dry bulk density

3.10.3 Porosity

Total porosity was calculated using the equation:

$$f = 1 - \frac{\rho b}{Ps} \qquad \text{(3.23)}$$

Where

f = porosity.

ρb = Bulk density of soil.

Ps = Particle density (2.65 gcm^{-1}).

3.10.5 Infiltration Measurements

Infiltrometer measurements were carried out in 2012 using the Kamphorts infiltromenter (double ring) (Anderson and Ingram, 1989). The double rings were hammered into the soil from the top of the rings up to 15 cm soil depth. A measurement of the vertical infiltration was taken at one minute then at 2 minutes interval until constant flow was attained. A graduated ruler was placed at the corner of the inner cylinder to record water levels at the defined time.

The infiltration data were analyzed according to the model of Kostiakov (1932) using Equation 3.24 which is frequently used in the tropical zone to characterize infiltration.

$$I = Ct^{\propto} \qquad \text{(3.24)}$$

Where

I = cumulative infiltration (cm)

C= initial infiltration $(cm\ min^{-1}\ or\ cm\ h^{-1})$

α = Index of sorptivity which reflects decline of infiltration rate

Plate 3. 1: Double Ring Infiltrometer for Infiltration rate Determination.

3.11 Estimation of Erosivity Index

Thirty-five 35 year annual rainfall data (1977 - 2012) for Upper East Region (MoFA, 2013) and (1977-2012) for the Northern Region (SARI, 2012) were used for this analysis. Using the data, rainfall distribution graph was plotted and moving average imposed on the graph.

Rainfall erosivity of the study area was estimated using the Modified Fournier Index (MFI) (Arnoldus, 1980). The method was considered ideal due to the fact that rainfall data in the study area lack rainfall intensity records necessary to compute rainfall erosivity using the $EI_{30\ \text{index}}$, (Wischmeier and Smith, 1978). The Modified Fournier Index (MFI) was calculated using the equation:

$$(MFI) = \sum p^2/P \quad (3.25)$$

Where

p = rainfall amount of each month of the year.

P = yearly rainfall amount.

3.12 Comparison of Nutrient Status of Participant Sites and Non-participant Sites

Two step approaches were used. First, comparison of nutrient contents among the study locations was performed using the analysis of variance. The level of degradation and deterioration of physical and chemical properties of farmlands was compared between participants and non-participants farmlands. Analysis of variance was used to test for significant differences between these categories.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Introduction

The chapter discusses the results obtained on soil physical properties and soil chemical properties identified on sampled fields. The results obtained were compared with baseline data or pre-data obtained from a study in 2008. In addition, comparison of means between participant and non-participant plot, as well as rainfall distribution and erosivity index of the study area are considered in this chapter. Results from infiltration measurements using infiltration model are also discussed in this chapter.

4.2 Infiltration Characteristics of Soils in the Study Area

According to (Chou, 1964), infiltration can be considered as a three step sequence: surface entry, transmission through the soil, and depletion of storage capacity in the soil.

Table 4. 1: Infiltration Characteristics among Soils Sampled on Participant Farm in the Kumbugu District

Community	Initial infiltration rate (mm/h)	Steady infiltration rate (mm/hr)	Cummulative infiltration(mm)	Kostiakov's model		
				α	C	R^2
Nwodua UP	10	5	267	0.68	1.031	0.99
Nwodua DS	5	5	54	0.44	0.78	0.99
Mbanayili UP	11	4	414	0.89	0.75	0.99
Mbanayili DS	11	4	272	0.67	1.032	0.99
Kpilo UP	12	8	298	0.51	0.45	0.98
Kpilo DS	3	5	35	0.615	1.032	0.99
SD	3.72	1.47	148.56	0.16	0.23	
C.V %	43	28	67	25	28	

Table 4. 2: Infiltration Characteristics among Soils Sampled on Participant Farm in the Kasena Nankani East Muncipality

Table 4.1 and Table 4.2 presents the infiltration rate among soils found on resource poor farmer's farm at Nwodua, Kpilo and Mbanayili in the Kumbugu district and Nyangua and Tono (Ecof) in the Kasena Nankani east municipality.

Community	Initial infiltration rate (mm/h)	Steady infiltration rate (mm/h)	Cumulated infiltration (mm)	Kostiakov's model		
				α	C	R^2
Nyangua UP	2	4	38	0.36	0.287	0.89
Nyangua DS	11	5	118	0.78	1.354	0.98
Ecof UP	10	10	456	0.55	1.0531	0.99
Ecof DS	24	5	515	0.55	1.323	0.99
SD	7.89	2.35	206.76	0.15	0.43	
C.V%	67	39	73	27	43	

Initial one-minute infiltration and cumulative infiltration after two hours elapsed time revealed a high variation with C.V value >35 of 43 % and 67 % among soils sampled on direct beneficiary farms in the Tolon district whiles soils sampled in the Kasena Nankani east municipality reveals C.V values > 35 % of 67 % and 73 % respectively. Initial one-minute infiltration and cumulative infiltration values presented on Table 4.1 and Table 4.2 conforms to the rating as reported by Mulla and Mc Branty (2001). Curve fitting using the least square method was used to obtain the index of soil sorptivity and initial infiltration (sorptivity) of Kostiakov's model for predictions. From Table 4.1, the co-efficient of determination (R^2) range from 0.98 to 0.99 at Nwodua, Kpilo and Mbanayili upstream and downstream respectively whiles table 4.2 presents a co-efficient of determination (R^2) range from 0.89 to 0.99 at Nyangua and Tono (Ecof) upstream and downstream. Co-efficient of determination (R^2) values presented on table 4.1 and table 4.2 implies that the model accounted for almost all variability in the data and indicated that Kostiakov's model for prediction provides a very good fit to the data. The index of sorptivity relates to the infiltration capacity (α); a higher value of α indicates a higher sorptivity rate of the soil. Table 4.1 presents an infiltration capacity value of 25 % while table 4.3 % for selected communities in at Kumbugu district and Kasena Nankani east municipality respectively. the infiltration capacity values presented on table 4.1 and 4.2 for the selected communities at the study area indicates that there is a moderate variability in infiltration among soils sampled during the field studies with values presented ranging between 15 % ≤ C.V≤ 35 % as reported by Mulla and Mc Bratney (2001). Moderate variability indicates that there is the need to encourage resource poor farmers to take more steps to practice adequately cover cropping, with compost, green or farmyard manure application (Glisic and Milosevic, 2009; Jelic *et al.* 2007; Sulieman and Buchroithner, 2008) or temporary abandonment of farm land (Abubaker, 1996; Wezel and Haigis, 2000; Wezel and Haigis, 2002) in other to promote better soil health.

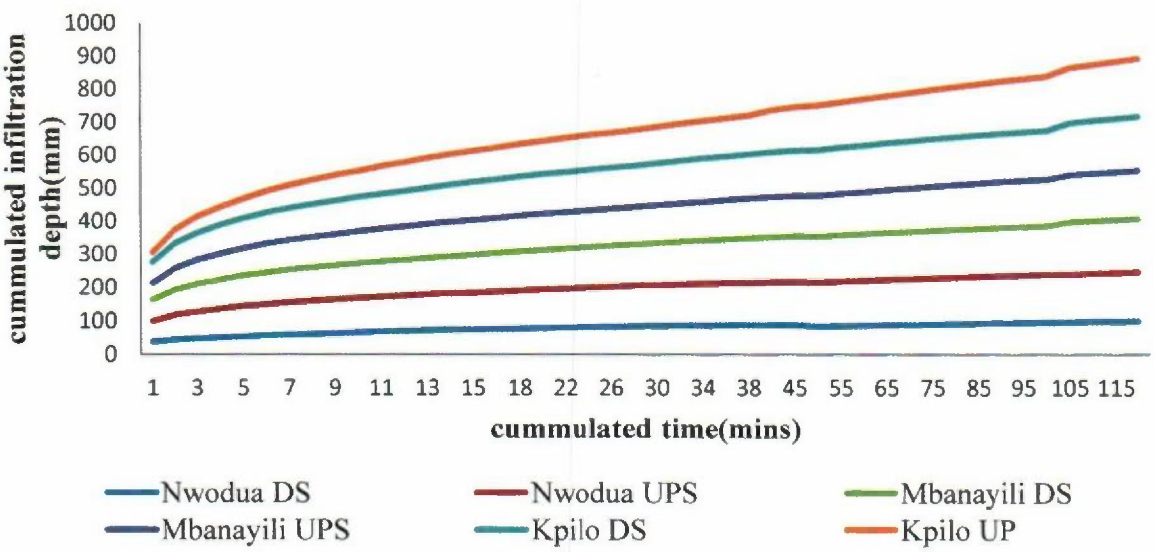


Figure 4. 1: Cumulative Infiltration Depth Curves for Participant Farms in the Kumbugu District

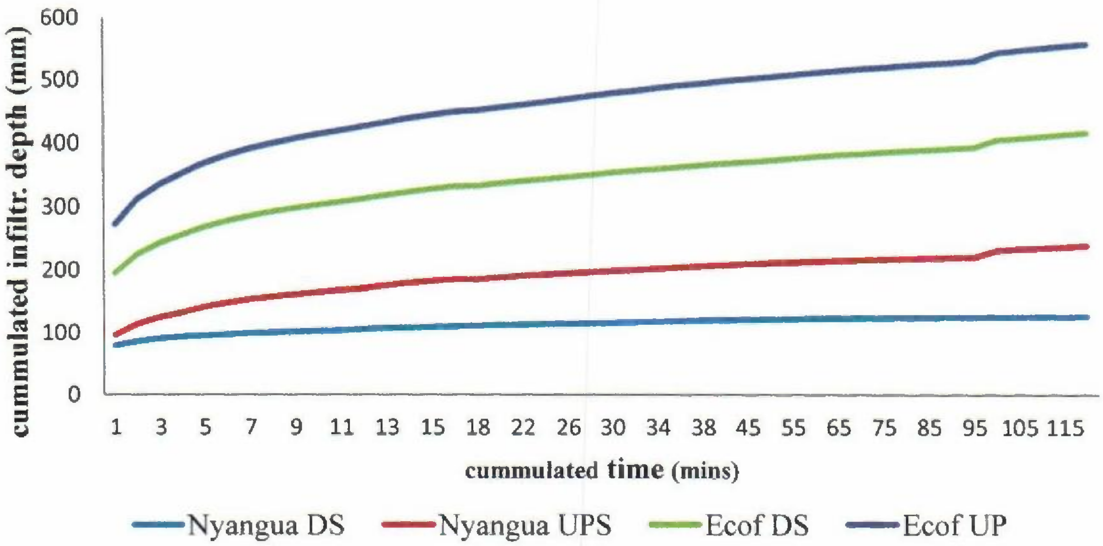


Figure 4. 2: Cumulative Infiltration Depth Curves for Participant Farms in the Kasena Nankani East Municipality

Generally for agricultural soils, the greater the vegetative cover the greater the time of disturbance and the higher the cumulative infiltration. In spite of this, vegetation and land use can greatly influence infiltration rates through modification of soil porosity, pore size distribution and through interception of raindrops by plant canopy. From (Figure 4.2) it can be noticed that Kumbugu downstream exhibits the highest cumulative infiltration rate. This may be as a result of the transportation, deposition and decomposition of highly grazed pasture (Holtan and Kirkpatrick, 1950) and sandy loamy nature of soil CPWF (2008), whiles Nyangua is generally exhibiting some level of compaction due to clay loamy CPWF (2008) nature of soil that does not readily enhance infiltrability of water as reported by Hillel (1982). It can also be seen from Figure 4.1 and Figure 4.2 that at Mbanayili, both upstream and downstream, Kpilo upstream and downstream, Nwodua upstream and Tono upstream show the same rate of cumulative infiltration. These findings agree with the (Hulugalle *et al.* 1986; Lal *et al.* 1979), whiles Nwodua downstream indicated the lowest cumulative infiltration. This may be as a result of hardpan inhibited continuous down flow of water.

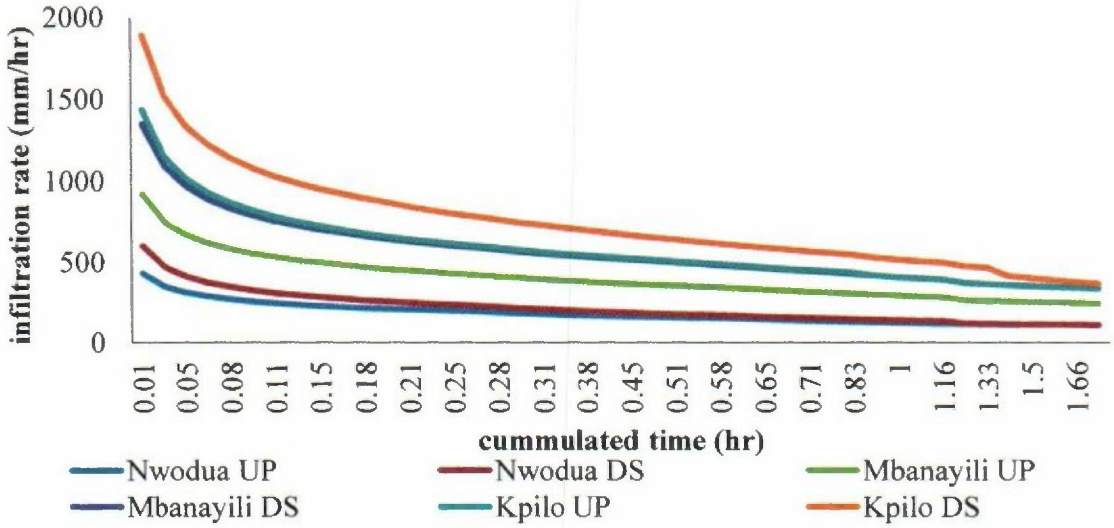


Figure 4. 3: Infiltration Rate Curves for Participant Farms in the Kumbugu District

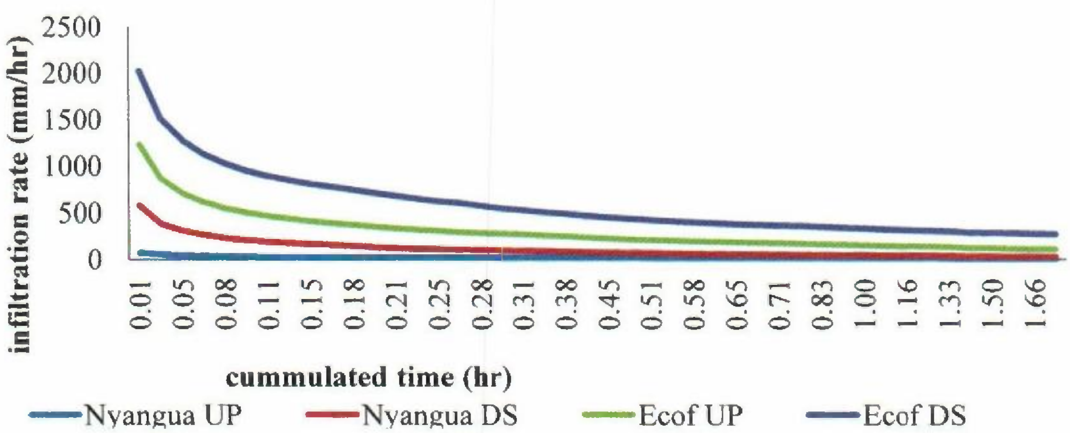


Figure 4. 4: Infiltration Rate Curves for Participant Farms in the Kasena Nankani East Municipality

From (Figure 4.3) and (Figure 4.4) it can be observed that soils sampled were characterized by decreasing infiltrability with time. Soils sampled from Ecof upstream and downstream had a high infiltration rate at the onset of infiltration at 654 mm/h and 794 mm/h, respectively. This findings conforms to FAO (1963) description of category of infiltration with point steady upstream and downstream where they obtained an infiltration rate of 209 mm/h and 198 mm/h respectively indicating very rapid and rapid infiltration. This indicates that downstream sample had higher infiltration rate than upstream. Soils from Mbanayili were characterized by very rapid infiltration rate on the onset, both at upstream 318 mm/h and downstream 342 mm/h with rapid steady infiltration rate at upstream 228 mm/h and downstream 199 mm/hr. The high infiltration of soils upstream and downstream can be related to the soil conservation techniques practiced on site such as composting and crop rotation with alley farming CPWF (2008). At Kpilo, upstream soil exhibited moderate infiltration rate of 85 mm/h, with very rapid initial infiltration at downstream (454 mm/h). In addition, at the point of stability, infiltration rate was 13 mm/h and 110 mm/h, respectively. The moderate infiltration rate at the upstream was due to the compact nature of the soil (silty loam). Furthermore, the top soil has been eroded. Similar observations were made for Nyangua, with infiltration rate being moderate at the upstream and very rapid infiltration rate at the downstream 72 mm/h upstream and 502 mm/h downstream with steady infiltration rate of 17 mm/h and 41 mm/h. In other to limit excessive nutrient loss from upstream to downstream due to run-off at Kpilo, Nwodua Nyangua and Ecof, construction of barriers, stone bunding and growing vertiver grass should be encouraged, as practiced at Mbanayili. In addition, mulching is the most effective way of conserving soil, as it results in the least soil loss, compared to the other methods, such as no-tillage, minimum tillage, ridging across slope and mixed cropping may also be effectively practiced in the study area.

4.2 Rainfall Characteristics of the Study Area

Rainfall characteristics are of utmost importance in the Kumbugu district and Kasena Nankani east municipality because it plays a major role in agriculture (Atengdem and Dery, 1998). Rainfall data for Kumbugu district and Kasena Nankani east municipality were used in the analyses and subsequent discussions of the rainfall situation of the various study area. Below are the annual rainfall variation and three year moving average for thirty-five years for Kumbugu district and Kasena Nankani east municipality.

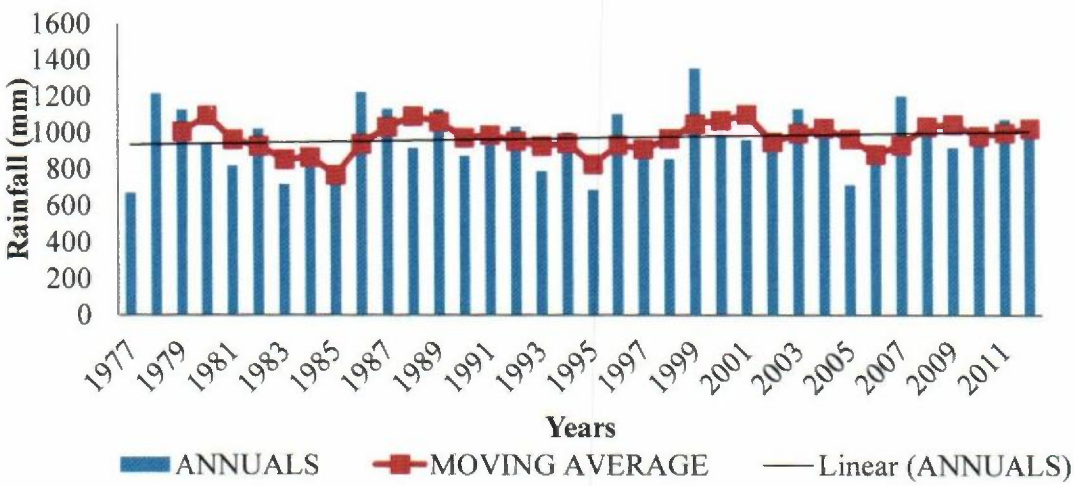


Figure 4. 5: Annual Rainfall Variation and 3-year Moving Average for thirty-five years for Kasena Nankani East Municipality

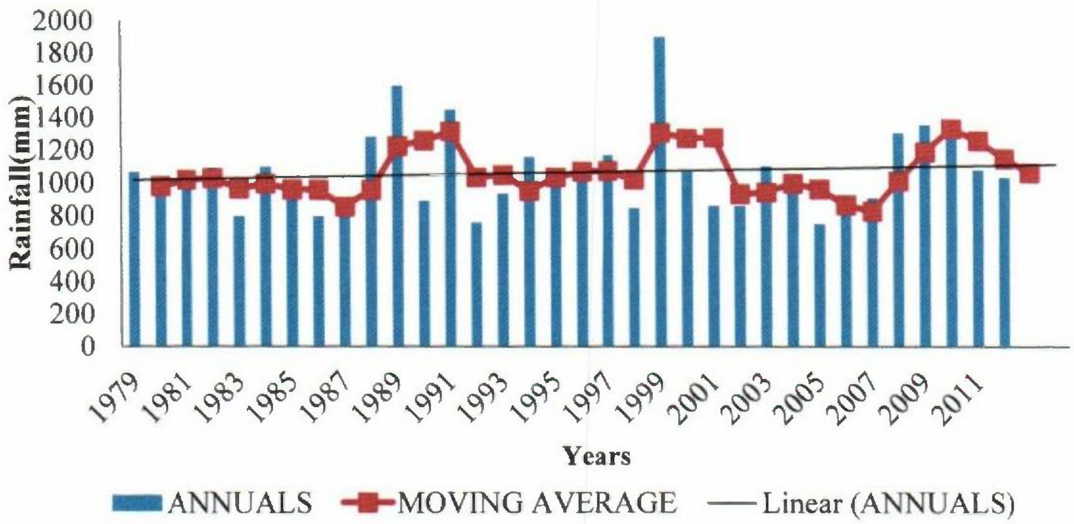


Figure 4. 5: Annual Rainfall Distribution and 3-year Moving average for thirty-five years for Kumbugu District

The average annual rainfall amount from (Figure 4.5) for the period of thirty-five years (35 years) (1977-2012) was 992 mm for Kasena Nankani east municipality in the Upper East Region, where Nyangua and Ecof communities are located, whiles in Kumbugu district (Figure 4.6) rainfall averages was 1147 mm for the same period. During the period, the lowest rainfall recorded in the Kasena east municipality occurred in 1995, with an amount of 688 mm, followed by 1983 with an amount of 719 mm, while the highest rainfall recorded during the period was 1353 mm in 1999, followed by a record of 1225 mm in 1986 (Figure 4.5).The lowest rainfall recorded in the Kumbugu district occurred in 2005 with an amount of 749 mm followed by 757 mm in 1992 whiles the highest rainfall for the period was 1898 mm in 1999 and the second highest occurred in 1989 with an amount of 1597 mm (Figure 4.6). According to Dietz *et al.* (2004) rainfall figures above 106 mm for Kasena Nankani east municipality and 940 mm for Kumbugu district implies there is adequate soil moisture to support crop production in the areas.

If drought is defined as a period of protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield (NDMC, 1998) then from 1977-2012, and 12 out of 35 years could be regarded as period of drought (Figure 4.6) for Kumbugu district. For Kasena Nankani east municipality, within the same period, 13 out of the 35 years could also be regarded as drought years Figure 4.5. This does not confirm the findings of Ofori-Sarpong (2001) that Northern region and Upper East Region suffer drought spelt.

According to Kranjac-Bersavijevic *et al.* (1998) in other to conserve moisture around the root and feeding zone of the crops, weeds (mulch) may be incorporated into the mounds to improve the fertility of the soil when they decompose. This helps to minimize the erosion rate in the area.

4.4 Rainfall Potentials of Soils in the Study Areas

Modified Fournier index predicts the ability of precipitation to cause erosion. Figure 4.6 and figure 4.7 depicts the comparison of modified Fournier index for Kasena Nankani East municipality and Kumbugu district for the period of thirty-five years.

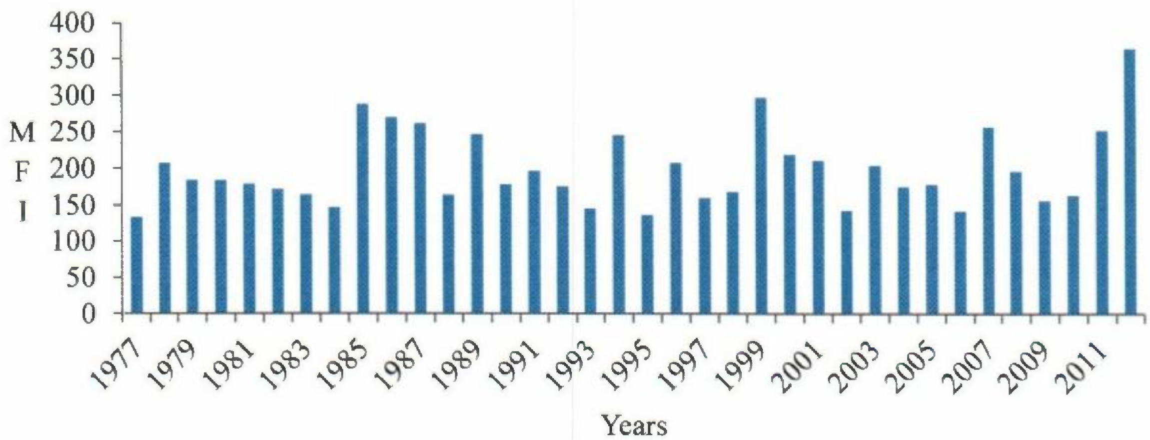


Figure 4. 6: Modified Fournier Index for Kasena Nankani East Municipality

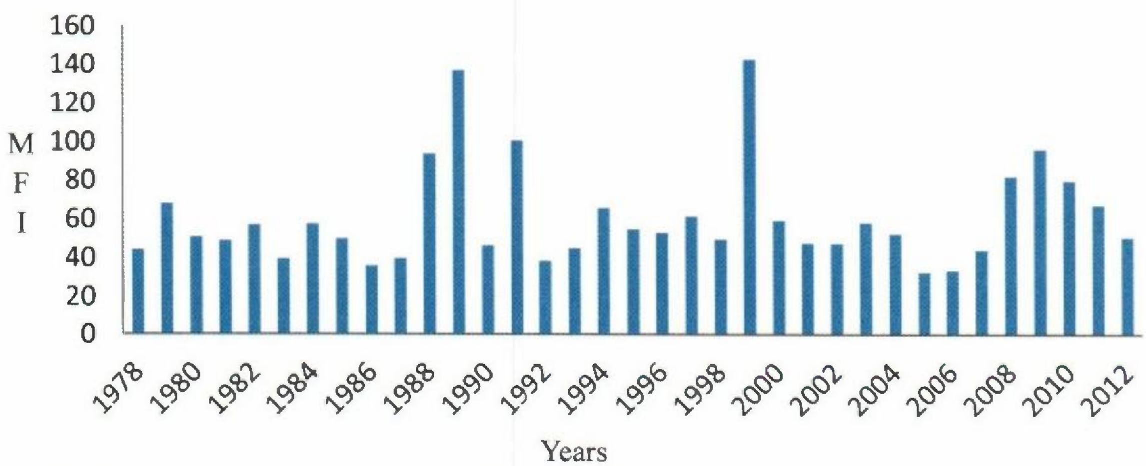


Figure 4. 7: Modified Fournier Index bar chart for Kumbungu District

From the graphs ability of rainfall to cause erosion was sinusoidal, with Kasena Nankani East municipality showing an increase in the ability for rainfall to cause erosion compared to that of

Kumbugu district. In addition, 1979 to 1985 depicts a period with quite a constant high erosivity at both locations with an increase in 1986 and a fall in 1988 at Kasena Nankani East municipality in the Upper East Region, while in the Northern region there is a continuous decrease to 1986 and a rise in 1988. This shows that occurrence of erosion as a result of rainfall varies and is not constant each year. The highest erosivity in the Kasena Nankani East municipality was in 2000, followed by 1998 with MFI values of 298 and 288, respectively whiles the lowest recorded was in 1977, followed by 2007 with MFI values of 133 and 143, respectively. Higher MFI values for the Kasena Nankani East municipality confirm the rating of > 160 (Corine, 1992) as very high, for 2000 and 1998, while lower MFI values between 120-160 reveals a high possibility of erosion occurrence. Furthermore, the highest MFI value recorded was in 1992 as 143, followed by 1989 with 137, while the lowest MFI was recorded in 2005, as 33, followed by 1986 as 36. MFI values for 1992 and 1989 confirmed a high rating (120-160), while MFI for 1986 and 2005 confirms a very low rating (< 60) for erosion to occur. Furthermore, low erosivity values occurring could be explained by relatively low amount of rainfall and high temperatures which could make most of the rainfall amount in the season lost through evapotranspiration as explained by Odunze (1995).

In general, the study revealed an MFI value of 200 for Kasena Nankani East municipality, whiles MFI value of 61 for Kumbugu district which confirms the ratings of Corine, (1992) that capacity of rainfall to cause erosion in the Kasena Nankani East municipality where Nyangua and Ecof (Tono) are located will be higher than that of Kumbugu district where Nwodua, Kpilo and Mbanayili are located in the Northern region. The MFI value of 200 for Kasena Nankani East municipality results obtained indicates that rains in the area are high enough to cause severe soil loss and nutrient transport, especially from the upper catchment to the valley bottom.

4.5 Soil Properties

The status of the soil properties (Table 4.3) and (Table 4.4) affect intended outcomes from the soil and water technologies introduced and implemented by resource poor farmers across a given area.

Table 4. 3: Some Soil Properties on Selected Farmers' Fields in the Kumbungu District

Soil structural properties		BD(g/cm^3)	POROSITY (%)	SOM(g/kg)	OC (g/kg)	Cc (t/ha)
Nwodua	P	1.72	34	6.4	0.95	3.65
	NP	1.89	29	5.5	0.82	2.85
	pre data	1.55	42	5.1	0.87	5.09
Kpilo	P	1.58	41	5.7	0.98	2.34
	NP	1.6	39	7.6	1.31	5.22
	pre data	1.47	45	7.2	1.23	7.18
Mbanayili	P	1.69	37	4.6	0.79	2.31
	NP	1.73	35	4.4	1.31	2.07
	pre data	1.5	43	7.55	1.29	7.48

P = Participant NP = Non-participant

Bulk density values ranged from 1.58 g/cm^3 to 1.72 g/cm^3 for participant farms whiles, non-participant farms ranged from 1.60 g/cm^3 to 1.89 g/cm^3. Agyare (2004) reported that the bulk density of soils in the tamale area ranged from 1.15 g/cm^3 to 1.89 g/cm^3 in the top soil and 1.10 g/cm^3 to 1.93 g/cm^3 in the sub soil. It was evident that bulk densities of the non-participant farm were somewhat higher than the participant farms thus emphasizing the beneficial effect of soil and water technologies practiced on the participant farms.

Bulk density of soil sampled at Nwodua, Kpilo and Mbanayili ranged from 1.58 g/cm^3 to 1.72 g/cm^3 as compared to the pre-data which reveals a range of 1.47 g/cm^3 to 1.55 g/cm^3. According to Bonsu and Asubio (2000) and Mengel and Barber (1974) reported that soils of the savannah area have low organic matter content and hence low nutrient status resulting in generally high bulk density. It can further be deduced that an increase in bulk density value on the direct beneficiary farm as compared to the pre-data is as a result of reduction in practicing composting and mulching CPWF (2008).

The porosity value was higher at participant farms as compared to that of non-participant farms at Nwodua, Kpilo and Mbanayili. The porosity of participant farm ranged from 34 % to 41 % whilst porosity on the non-participant farm also ranged from to 29 % to 39 % as seen on Table 4.3. The increase in total porosity could be attributed to increase in percentage of micro-pores. Macro-pores are transmission pores and if stable ensure more water intake and less run-off and erosion from land (Mbagaw, 1992). Again porosity from the pre-data presented from table 4.4 indicates a range from 41 % to 45 % as compared to the participant farm of 34 % to 41 % at Nwodua, Kpilo and Mbanayili. The decrease in porosity value on the non-participant farm as compared to the non-participant farm is as a result of reduction in the practice of soil and water conservation technologies such as composting and mulching according to CPWF (2008) report. Composting when applied stimulates the activity of macrofauna such as earthworms which create burrows lined with glue-like secretion from their bodies and are intermittently filled with worm cast material. Increased levels of organic matter and associated soil fauna lead to greater pore space with the immediate result that water infiltrates more readily and can be held in the soil (Roth, 1985). Improved pore space results in good drainage, enhanced aeration, and promote root growth.

It was equally noticed from table 4.3 that there has being a decrease in soil organic matter, organic carbon and carbon accumulation among participant farms as compared to the pre-data CPWF (2008). Soil organic matter has been reported by Obi and Ebo (1995) to stabilize soil structure, thereby reducing soil bulk density and increasing porosity. Moreso, it has been reported that the addition of organic materials into the soils reduces bulk density and increases porosity (Anikwe, 2000; Marinari *et al.* 2000; Candemir and Gulser, 2011). Soil organic matter presented on table 4.3 at Nwodua, Kpilo and Mbanayili ranged from 0.79 g/kg to 0.95 g/kg on the participant farm; whiles organic matter on non-participant farm ranged from 0.82 g/kg to 1.31 g/kg.

Again decline in soil organic matter from 0.87 g/kg to 1.29 g/kg as reported by (CPWF, 2008) compared to the results presented on table 4.4 shows a clear evidence that farmers at Nwodua, Kpilo and Mbanayili continuously remove plant material for human consumption and animal consumption with relatively little replenishment to the soil (Abagale *et al.* 2012).

As indicated on table 4.4 soil organic carbon content range from 4.6 g/kg to 6.4 g/kg on participant farm, 4.4 g/kg to 7.6 g/kg on non-participant farm and 5.1 g/kg to 7.55 g/kg from pre-data presented. Decrease in soil organic carbon on the participant farm at Nwodua, Kpilo and Mbanayili may be due to continuous cultivation with less recycling of crop residues as reported by Andrews (2006) and Ogbodo (2009). It can be noticed from table 4.3 that carbon accumulation range from 2.31 t/ha to 3.65 t/ha participant farm whiles non-participant farm records value ranging from 2.07 t/ha to 5.22 t/ha. The pre-data value presented on table 4.3 ranges from 5.09 t/ha to 7.48 t/ha at Nwodua, Kpilo and Mbanayili.

Table 4. 4: Some Soil Properties on Selected Farmers' Fields in the the Kasena Nankani East Municipality

Soil structural properties		BD(g/cm^3)	POROSITY (%)	OC (g/kg)	SOM(g/kg)	Cc (t/ha)
Nyangua	P	1.83	22	7	1.2	3.83
	NP	1.93	13	8	1.38	4.64
	pre data	1.7	36	6.8	1.16	6.78
Ecof	P	1.67	36	5.3	0.91	2.84
	NP	1.92	20	4.8	0.83	3.79
	pre data	1.8	32	5.8	0.99	5.78

P= Participant Non-participant = Non-participant

From Table 4.4 it can be noticed that the bulk density of soils sampled at Nyangua and Ecof ranged from 1.67 g/cm^3 to 1.83 g/cm^3 on the participant farm whilst on the non-participant farms ranged from 1.92 g/cm^3 to 1.93 g/cm^3. According to Shaver *et al.* (2003) high bulk density is an indicator of low porosity and high soil compaction. This implies that low bulk at the participant farms at Nyangua and Ecof enhances root growth and proper movement of air and water through the soils as compared to non-participant farms. Furthermore, from Table 4.4, comparing the pre-data value ranging from 1.77 g/cm^3 to 1.80 g/cm^3 to participant farm ranging from 1.67 g/cm^3 to 1.67 g/cm^3, it can therefore be deduced that increase is an evidence of soil compaction which can result in shallow plant rooting and poor plant growth, influencing crop yield and reducing vegetative cover available to protect soil from erosion USDA (2008). If bulk density of soil is high, then the emerging plumule would be unable to overcome the resistance of overlying soil and would therefore result in decreased emergence of the seedling (Navedita, 1992).

From Table 4.4, the study indicated that porosity of soils sampled on the participant farms showed a higher value as compared to the non-participant farms at Nyangua and Tono (Ecof). Porosity value presented for the non-participant farm ranged from 13 % to 20 % whiles that of participant farm ranged 22 % to 36 % at Nyangua and Tono (Ecof) respectively. Pre-data revealed that porosity value obtained at Nyangua and Tono (Ecof) shows that the soils found there have small pore space and have the capacity to retain more water to make them available to the crops planted in them.

According to Das and Puste (2001), organic waste materials like crop residues, well decomposed cow dung, compost and other rural waste are considered highly useful resources in enhancing soil fertility and also in the build-up of soil organic matter. It can be observed from Table 4.3 presented that there is an increase soil organic matter ranging from 0.91 g/kg to 1.2 g/kg as compared to 0.83 g/kg to 1.38 g/kg on the non-participant farm. Increase in soil organic matter on the non-participant farm is as a result of continuous replenishment of soil and water techniques adopted from the non-participant farmer. The pre-data from CPWF (2008) revealed a value of 1.16 g/kg which increased to 1.2 g/kg on the direct beneficiary at Nyangua whiles the pre-data results presented on table 4.4 reveals a value 0.99 g/kg as compared to 0.91 g/kg on the participant farm at Ecof. This reduction in value in soil organic matter may be as a result of and high temperature.

In addition to the above, it can be noticed that soil organic carbon range from 5.3 g/kg to 7.0 g/kg on participant farm and 8.0 g/kg on non-participant farm as compared to the pre-data value range from 5.8 g/kg to 6.8 g/kg. According to Young (1996), tropical crops need average soil organic carbon content for proper growth and development. Nevertheless, the current result presented on Table 4.3 suggests that an increase in soil organic carbon on non-participant farm at Nyangua and Ecof as compared to participant farm fell within the recommended range. Furthermore table 4.4 reveal carbon accumulation value ranging from 2.84 t/ha to 3.83 t/ha whiles on non-participants it was noticed that carbon accumulation range from 3.79 t/ha to 4.64 t/ha. In contrast to the participant, the pre-data reveal that carbon accumulation range from 5.78 t/ha to 6.78 t/ha at Nyangua and Ecof.

4.6 Soil Nutrients Levels

As presented clearly on Table 4.7 average pH concentration values on the participant farm decreased at Nwodua and Kpilo with values indicating 5.56 and 5.79 as compared to 5.31 and 5.65 on the non-participant farm respectively.

Table 4. 5: Soil Chemical Properties on Selected Farmers' Fields in the Kumbugu District

Community		pH	N (%)	P(g/kg)	K(cmol⁺/kg)	CEC(cmol⁺/kg)
Nwodua	P	5.56	0.05	2.92	0.12	3.83
	NP	5.31	0.03	2.28	0.13	3.39
	pre-data	4.8	0.04	2.7	0.19	2.4
Kpilo	P	5.79	0.04	1.67	0.17	5.21
	NP	5.65	0.05	3.06	0.1	5.83
	pre-data	6.2	0.07	5.1	0.25	2.8
Mbanayili	P	5.27	0.04	3.14	0.09	2.15
	NP	5.36	0.03	3.92	0.1	2.08
	pre-data	5.1	0.05	3.3	0.31	3.7

P= Participant NP= Non-participant

Furthermore there has being an increase in pH value of 5.36 on the non-participant farm as compared to a value of 5.27 on the participant farm. The pre-data values reported from CPWF (2008) at Nwodua, Kpilo and Mbanayili as 4.8, 6.2 and 5.1 as compared to pH values of 5.56, 5.79 and 5.1 respectively.

According to Millar and Baggs (2004) and Yunsheng *et al.* (2007) organic wastes gotten from soil and water technologies practiced by farmers can influence soil pH through accumulation of carbon dioxide and organic acid during their decomposition in the soils. Furthermore Lap (1990) reported that soil pH < 6.6 is the best condition for growing cereals such as rice and it can produce higher yield than neutral alkaline soil. However, pH concentrations for both participant farm, indirect beneficiary farm and the pre-data presented on Table 4.5 fell below the recommended standard and it's good for crop cultivation.

Nitrogen is present in soils in organic and inorganic form. Nitrogen is critical from the development of green leaves and is made available to plants as nitrate and ammonia. Nitrate is also produced by mineralization of organic matter and can also easily leached (MSU extension, 2011). From table 4.5 nitrogen content ranges from 0.03 % to 0.05 % on participant farm as Nwodua, Kpilo and Mbanayili as compared to the pre-data ranging from 0.04 % to 0.07 %. Decrease in nitrogen values presented on table 4.5 on participant farm as compared to the pre-data value corroborates with (MoFA, 2010) report on soil fertility status of northern region with nitrogen content ranging from 0.02 % to 0.05 %.

Soils sampled taken from the study are at Nwodua, Kpilo and Mbanayili in the Kumbugu district revealed that, phosphorus ranged from 1.67 g/kg to 3.14 g/kg on participant farm and 2.28 g/kg to 3.92 g/kg on non-participant farm. It was furthermore noticed that low available soil phosphorus values presented on the participant farm at Nwodua, Kpilo and Mbanayili as compared to that of non-participant farm may be attributed to inadequate organic matter on the participant farm resulting in the low phosphorus level. This could also be as a result of available phosphorus removal or lost from the soil by crop uptake and removal, runoff and erosion and leaching (Gregory, 2009). Again from table 4.5 Phosphorus value ranged from 2.70 g/kg to 5.1 g/kg from the pre-data obtained from CPWF (2008) report as compared to values noticed on the participant farms may cause reduced growth, sometimes stunted and other times only evident from shortened internodes, smaller leaves and reduced tillering in cereals and poor seed development (Jeremy, 2002).

As presented on Table 4.5, potassium values ranged from 0.09 $cmol^{+}/kg$ to 0.12 $cmol^{+}/kg$, 0.1 $cmol^{+}/kg$ to 0.13 $cmol^{+}/kg$ and 0.19 $cmol^{+}/kg$ to 0.31 $cmol^{+}/kg$ on participant farm, non-participant farm and pre-data presented respectively. the results presented on table 4.4 clearly indicates that there is a decrease in available potassium on participant farms as compared to the pre-data value noticed in the CPWF (2008) report at Kpilo, Nwodua and Mbanayili. Generally potassium values presented on table 4.4 are low as presented by FAO (1976) rating of soil fertility for crop production for tropical soil as <0.15 $cmol^{+}/kg$. Inadequate potassium levels on participant as compared to pre-data presented may cause reduction in plant susceptibility to insect and disease attack (ASFG, 2010).

From Table 4.5 it can be noticed that CEC values on participant farm range from 2.15 $cmol^{+}/kg$ to 5.21 $cmol^{+}/kg$ whiles the non-participant farm range from 2.08 $cmol^{+}/kg$ to 5.83 $cmol^{+}/kg$. FAO (1976), description of soil fertility rating for crop production for tropical soils. It can further be noticed that the pre-data presented 2.4 $cmol^{+}/kg$ to 3.70 $cmol^{+}/kg$ as compared to that of the pre-data on participant farm. General increase in CEC on participant farm as compared to the pre-data value presented implies that soils found on participant farms are less susceptible to leaching losses of cations such as potassium and magnesium (Quirine *et al.* 2007).

Table 4. 6: Soil Chemical Properties on Selected Farmers' Fields in the Kasena Nankani East Municipality.

Community		pH	N (%)	P(g/kg)	K(cmol$^+$/kg)	CEC(cmol$^+$/kg)
Nyangua	P	5.62	0.05	3.71	0.13	8.36
	NP	5.45	0.07	3.83	0.16	5.44
	pre-data	5.85	0.06	3.2	0.11	3.01
Ecof	P	4.92	0.05	4.63	0.07	2.13
	NP	4.72	0.04	8.24	0.07	1.71
	pre-data	5.7	0.04	5.8	0.43	2.6

P= Participant NP = Non-participant

From table 4.6 it can be noticed that there has been a decrease in pH value of 5.62 and 4.92 on participant farm at Nyangua and Ecof as compared to values of 5.45 and 4.72 on non-participant farms respectively. The pre-data revealed a pH value ranging from 5.7 to 5.85. According to He *et al.* (2003), most acidic soils have been found to be low in fertility, have proper poor physical, chemical and biological properties hence crop production on such soils is seriously constrained.

Nitrogen content from soils sampled was 0.05 % on the participant farm at Nyangua and Ecof as compared to pre-data value ranging from 0.04 % to 0.07 %. Drury *et al.* (2003) reported that the response of nitrogen mineralization to soil moisture varies with temperature. Temperature fluctuation in the savannah ecological zone may account for the reduction in nitrogen levels on the participant farms.

However, the decrease in nitrogen concentration on the participant at Nyangua and Ecof as compared to the pre-data might be due to leaching or immobilization of nitrogen commonly reported in northern region soils (Hubbard and Jordan, 1996) and also leaching of nitrogen through run-off, inadequate organic matter and continuous cropping (Kaizzi *et al.* 2002 and Dali *et al.* 2005).

From Table 4.6 Phosphorus values ranged from 3.71 g/kg to 4.63 g/kg on participant farm whiles non-participant farms revealed values ranging from 3.8 g/kg to 8.24 g/kg at Nyangua and Ecof. High values noticed on non-participant farms as compared to participant farms proves that the use of compost as organic fertilizer could supply soil with good amounts of available Phosphorus due to the high incorporation of crop residues that increase crop available Phosphorus by the process of biomass decomposition and release of Phosphorus from the biomass or increase in the amount of soluble organic matter which are mainly organic acids that increase the rate of desorption of phosphate and thus, improve the available Phosphorus content in the soil (Nziguheba *et al.* 1998). Again the pre-data from CPWF (2008) report revealed that value range from 3.2 g/kg to 5.8 g/kg whiles participant farms revealed values range from 3.71 g/kg to 4.63 g/kg. Phosphorus values noticed from the pre-data and participant farms conforms with the findings of (Dedzoe *et al.* 2002) who reported that available Phosphorus in the savannah ecological zone is low ranging from trace to 6.0 g/kg.

Table 4.6 reveals that there is an increase in CEC levels on direct beneficiary farm at Nyangua and Tono (Ecof) as compared to pre-data value range from 2.6 $cmol^+/kg$ to 3.01 $cmol^+/kg$. High levels of CEC noticed among soils sampled at Nyangua and Ecof is as a result of the influence of soil organic matter and clay minerals. Increase in soil organic matter through compost addition is likely to cause an increase in CEC MacConnel *et al.* (1993) in a review concluded that applying compost at normal agronomic rates will increase CEC of most mineral soils.

4.7 Comparisons of Means between Participant and Non-participant Farms

Table 4. 7: Analysis of Variance between Farms and Within Farms.

Parameter	Mean		Mean difference	Std. Deviation	T	Sig. (2-tailed)
	P	NP				
pH	5.45	5.28	0.17	0.5887	1.93	0.060
OC	0.52	0.53	0.02	0.2282	0.58	0.565
SOM	0.89	0.92	0.03	0.3925	0.58	0.565
Cc	5.14	5.34	0.20	2.2766	0.581	0.565
N	0.05	0.04	0.00	0.0220	1.252	0.217
P (g/kg)	1.30	4.31	0.302	3.0636	6.532	0.000
K ($cmol^+/kg$)	0.10	0.11	0.01	0.0946	0.802	0.427
CEC($cmol^+/kg$)	3.89	3.20	0.69	2.6173	1.751	0.087
BD (g/cm^3)	1.67	1.81	0.05	0.9440	0.364	0.718
GMC	0.07	0.22	0.15	0.4272	2.294	0.027
VMC	0.07	0.15	0.08	0.3892	1.352	0.183
Porosity	34	27.2	0.06	0.19	2.145	0.038

P= Participant NP= non-participant

The study revealed from Table 4.7 that there was no significant difference between participant and non-participant farm, with respect to pH, OC, SOM, Cc, N, K, BD, and VMC. However, P, GMC and porosity had significant differences between soils samples from participant farm and non-participant farm. From the study, it can be observed that mean soil organic matter values of 0.89 % and 0.92 %, for both participant farms and non-participant farms, respectively, were low. This is similar to the findings of Adu, (1969), 1975 and Fosu *et al.* (2004). Similarly, it can also be noted that mean values of 0.52 % and 0.53 % for organic carbon were very low. This result supports the findings of Udo *et al.* (1996). Low values of OC may be as a result of continuous cropping and high temperatures, coupled with unimodal rainfall with long and severe dry season that exposes the sparse grass vegetation and any remaining crop residues to annual bushfires and overgrazing. To revamp low soil organic matter, participant farmers may use strategies in maintaining or augmenting soil organic matter apart from manure application include mulching with crop residues, slashing weeds without burning, composting and natural fallowing, as reported by Quansah *et al.* (2001).

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In the Kumbugu district of the Northern Region and Kasena Nankani East municipality of the Upper East Region of the savannah agro-ecological zone of Ghana, a study was conducted on effects of soil and water conservation techniques on physical and chemical properties of soil in the savannah ecological zone on farmers' fields. The objectives of the study were to determine and compare nutrients status on participant site to non-participant to the pre-data from beneficiaries' of the CPWF project, determine bulk density, porosity, soil moisture content and infiltration. The reduction of soil bulk density generally on the direct beneficiary farm as compared to the non-participant farm is a possible consequence of increasing organic matter content which played a vital role in reducing compaction of soil. As source of organic matter the organic amendments promotes soil fauna activity and plays a major role in the build-up and stabilization of soil structure. The study also sought to study rainfall characteristics and thus, erosivity was estimated for prediction of run-off occurrences using MFI. Furthermore from the study it can be deduced that rainfall has become so variable that it has become too difficult to predict what the situation would be like during the cropping season. Intermittent droughts in the cropping season are becoming more pronounced and this is adversely affecting food production in the area.

Study was based on the hypothesis that SOM, OC, Cc, N, K, P, CEC in participant bench mark sites are significantly higher than non-participant bench mark sites whiles bulk density, porosity, soil moisture content and infiltration on the participant bench mark sites are significantly different than non-participant bench mark sites depicting that soil and water technologies techniques improved on participant farm than non-participant farms.

The results obtained from the study and subsequent discussion, the following conclusions can be drawn:

Soil properties such as bulk density, porosity, organic carbon, soil organic matter and carbon accumulation show variability among soils sampled on both participant farm and non-participant farm which is an indication that farmers still practice soil and water technologies introduce by Challenge Program on Water and Food such as composting, mulching but at a low pace.

Chemical properties such as pH, nitrogen, phosphorus, potassium and cation exchange capacity were generally low among soil sampled at the selected beneficiaries 'communities as compared to the pre-data obtained from the CPWF site.

Infiltration rate among selected farmer's farms shows high variability, with initial infiltration of sorptivity of Kostiakov's model indicating a moderate variation.

Rainfall in the Kasena Nankani east municipality of the Upper East Region shows considerable erodibility, when compared to Kumbugu district in the Northern Region. Average rainfall for Kasena Nankani east municipality during the study was 992 mm/annum, with modified Fournier index of 199, but for Kumbugu average rainfall was 1147 mm/annum, with modified Fournier index of 61.

From the studies conducted on both participant and non-participant farms in the various selected communities in the Kumbugu district and Kasena Nankani east municipality, it can be deduced that soil and water conservation technologies improved soil physical properties on the participant farms hence rejecting the null hypothesis and accepting the alternate hypothesis. Furthermore, SOM, OC, Cc, N, P, K, CEC were significantly higher on participant bench mark sites as compared to the indirect beneficiary bench mark sites hence accepting the alternate hypothesis and rejecting the null hypothesis.

5.2 Recommendations

Based on the research findings, the following recommendations are made:

Study should be conducted more on the participant farm and non-participant in the various study areas to know the levels of its chemical constituents to be able to establish a concrete relationship the soil's chemical properties and the source of materials used in compost preparation, the quantity of fertilizer applied during micro-dosing and proper erosion control techniques.

Government organisations in the agriculture sector such as MoFA and MiDA should encourage farmers to practice more of the soil and water technologies in other to reduce the cost of purchasing fertilizer in other to maximize profit.

Other non-beneficiary should adapt to the use of soil and water technologies in other to enrich the nutrient status of their soil for high yield.

In order for the donor-led projects to build more success stories for the various soil fertility management practices, the knowledge and experience acquired over the past years should be harnessed, repackaged and used. In this way, they will be able to convince the government on the benefits, of soil and water conservation technologies and its potential to resolve food security problems and promote a sustainable source of livelihood for rural small-scale farmers. This will enable support for the practices of soil and water technologies which should go further than the small scale farmers. This can be done through adaptive research targeting different groups of farmers in the different environments and socio-economic settings.

Further studies should be conducted to ascertain reasons accounting for low soil nutrients status on especially, participant farms.

The research should be repeated for a longer period to ascertain the lasting impact of soil and water technologies practiced on soil physical properties on both participant farms and non-participant farms.

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APPENDIX I

KUMBUGU

DISTRICT

YEARS	ANNUAL RAINFALL	MODIFIED FOURNIER INDEX	PRECIPITATION CONCENTRATION INDEX
1978	2856.2	44.12	1.55
1979	3044.3	68.12	2.24
1980	2972	50.74	1.71
1981	2981	48.84	1.64

1982	3076.8	57.05	1.85
1983	2784.7	39.55	1.42
1984	3085.9	57.44	1.86
1985	2969.4	49.94	1.68
1986	2786.7	35.92	1.29
1987	2788	39.65	1.42
1988	3277.8	93.64	2.86
1989	3597.7	137.07	3.81
1990	2891.5	46.37	1.60
1991	3451	100.66	2.92
1992	2764.1	38.38	1.39
1993	2940.7	44.90	1.53
1994	3166.1	65.81	2.08
1995	3017.1	54.83	1.82
1996	3054.1	52.85	1.73
1997	3184.1	61.56	1.93
1998	2865.7	49.41	1.72
1999	3919.2	142.85	3.65
2000	3088.3	59.36	1.92
2001	2885.1	47.51	1.65
2002	2887.1	47.48	1.64
2003	3130.5	58.27	1.86
2004	3056	52.33	1.71
2005	2782	32.55	1.17
2006	2853.4	33.64	1.18

2007	2942.9	43.91	1.49
2008	3343.9	82.04	2.45
2009	3395.4	96.13	2.83
2010	3375.7	79.72	2.36
2011	3121.9	67.23	2.15
2012	3077.3	50.57	1.64

KASENA NANKANI
EAST
MUNICIPALITY

YEAR	ANNUAL RAINFALL	MODIFIED FOURNIER INDEX	PRECIPITATION CONCENTRATION INDEX
1977	671.1	133.99	19.97
1978	1217.8	207.40	17.03
1979	1125.7	183.84	16.33
1980	940.3	183.66	19.53
1981	818.7	179.11	21.88
1982	1021.5	171.21	16.76
1983	719	164.54	22.89
1984	852.3	147.69	17.33
1985	733.5	288.38	39.32
1986	1225.2	269.96	22.03
1987	1133.1	261.97	23.12
1988	914.5	164.75	18.01
1989	1130	247.14	21.87
1990	870.7	178.31	20.48
1991	956	196.74	20.58
1992	1033.1	175.79	17.02
1993	789.4	146.46	18.55
1994	1001.2	245.89	24.56
1995	687.9	137.19	19.94
1996	1104	207.62	18.81
1997	940	160.30	17.05

1998	855.6	168.60	19.71
1999	1353.3	297.52	21.99
2000	991.1	219.11	22.11
2001	959.7	210.90	21.96
2002	896.2	143.49	16.01
2003	1134	204.36	18.02
2004	1048.9	175.54	16.74
2005	717.4	178.75	24.92
2006	876.9	142.85	16.29
2007	1201.4	257.55	21.44
2008	1022.7	197.17	19.28
2009	920.2	157.19	17.09
2010	1003.7	164.33	16.37
2011	1076.5	252.73	23.48
2012	992.2	365.63	54.48

APPENDIX 2: Analysis of variance between farms and within farms.

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between farms	12.4581	4	3.115	18.959	.000
	Within farms	20.8629	127	.164		
	Total	33.3211	131			
OC	Between farms	.6446	4	.161	4.081	.004
	Within farms	5.0155	127	.039		
	Total	5.6601	131			
SOM	Between farms	1.9070	4	.477	4.081	.004
	Within farms	14.8379	127	.117		
	Total	16.7449	131			
Cc	Between farms	64.1516	4	16.038	4.081	.004
	Within farms	499.1478	127	3.930		
	Total	563.2994	131			
N	Between farms	.0021	4	.001	1.472	.215
	Within farms	.0451	127	.000		
	Total	.0472	131			
P	Between farms	117.8357	4	29.459	5.724	.000
	Within farms	653.5645	127	5.146		
	Total	771.4002	131			
K	Between farms	.1240	4	.031	12.644	.000
	Within farms	.3114	127	.002		
	Total	.4354	131			
CEC	Between farms	549.1601	4	137.290	37.411	.000

	Within farms	466.0626	127	3.670		
	Total	1015.2226	131			
BD	Between farms	.2601	4	.065	.116	.977
	Within farms	71.4253	127	.562		
	Total	71.6854	131			
GMC	Between farms	.0813	4	.020	.099	.983
	Within farms	26.0787	127	.205		
	Total	26.1600	131			
VMC	Between farms	.2240	4	.056	.455	.768
	Within farms	15.6194	127	.123		
	Total	15.8435	131			
Porosity	Between farms	.0078	4	.002	.068	.991
	Within farms	3.6338	127	.029		
	Total	3.6416	131			