KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF ENGINEERING

EFFECT OF SOIL AND WATER CONSERVATION MEASURES ON COWPEA AND MAIZE PERFORMANCE IN THE NORTHERN AND UPPER EAST REGIONS OF GHANA

A THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL ENGINEERING IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PHILOSOPHY IN SOIL AND WATER ENGINEERING

By

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DECLARATION

This thesis is a presentation of my original research work. Wherever contributions of others are involved, it is indicated clearly with due reference to the literature and acknowledgement of authors, and that it is neither in part nor whole been presented for another certificate in this university or elsewhere.

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ABSTRACT

Agricultural land in Ghana is being degraded, with soil erosion becoming an increasing threat to crop production. Soil and water conservation (SWC) practices are promising intervention especially if developed to suit a given climate, soil type as well as crops. This study was set out to evaluate the impact of four treatments [contour farming (CF), half-moon (HM), contour ridges (CR) and farmer's practice (FP)] on cowpea and maize growth and yield as well as on soil moisture content. A survey was used to assess farmers' level of knowledge on soil erosion and erosion control practices as well as factors that cause soil erosion. The study was carried out in the Northern and Upper East Regions of Ghana on-station and on-farm using cowpea and maize as test crops. The on-station experiment consisted of four replicates each of cowpea and maize with the four treatments. The on-farm experiment was carried out in six communities across the Northern and Upper East Region of Ghana with each community as a replicate. Plant height, stem girth, root biomass, number of leaves, leaf area index (LAI) at flowering/tasseling and grain yield were determined. The on-station experiment showed that SWC measures significantly ($P < 0.05$) retained more moisture compared to the farmers' practice. In the cowpea trial, there was about 23.4%, 19.2% and 17.8% significant ($P < 0.05$) retention in soil moisture in the CF, CR and HM treatments respectively over the FP whilst in the maize trial, CF, CR and HM recorded about 24.0%, 20.4% and 19.4% significant ($P < 0.05$) retention in soil moisture over the FP respectively. Only cowpea stem girth was significantly affected ($P < 0.05$) by SWC measures. Effect of SWC measures on cowpea in the Upper East was only significant ($P < 0.05$) for the LAI whilst significant effect ($P < 0.05$) of SWC measures on cowpea in the Northern Region was observed on stem girth, LAI, root biomass and yield. The SWC measures effect on maize at the on-station trial were significant ($P < 0.05$) on maize height, stem girth, root biomass and yield. The Upper East maize trial recorded significant effect ($P < 0.05$) of SWC measures on maize height, LAI and yield whilst the Northern Region maize trial recorded significant effect ($P < 0.05$) of SWC measures on yield only. Where there was no significant treatment effect ($P < 0.05$) on the growth and yield components of the cowpea and maize performed better with the SWC measures (CF, HM and CR) compared to the control (FP). The survey revealed that all the respondents in both regions were aware of what soil erosion is about. All respondents had knowledge of soil erosion whilst 85% of respondents across the two regions had knowledge or were aware of SWC measures as erosion control techniques. The respondents agreed that the causes of soil erosion included cultivation on steep slopes, poor SWC practices, excessive rainfall, population pressure, over cultivation, deforestation and over grazing. All respondents rated erosion as a severe problem and mentioned that the rate of soil erosion has been increasing over time. They were aware that erosion can be controlled. Farmers in the Northern and Upper East Regions of Ghana should adopt soil and water conservation (SWC) measures especially contour farming (CF) for maize and cowpea production.

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LIST OF ABBREVIATIONS

AfDB	African Development Bank
CBA	Cost-Benefit Analysis
CORAF	Conseil ouest et centre africain pour la recherche et le développement agricoles
FAO	World Food and Agriculture Organisation
GDP	Gross Domestic Production
GSGDA	Ghana Shared Growth and Development Agenda
GSS	Ghana Statistical Service
IBSRAM	International Board for Soil Research and Management
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculcure
ISRIC	International Soil Reference and Information Centre
IUSS	International Union of Soil Science
IWMI	International Water Management Institute
MoFA	Ministry of Food and Agriculture
NPV	Net Present Value
PRONAF	Programa Nacional de Fortalecimento da Agricultura Familiar
SARI	Savanna Agricultural Research Institution
SECAP	Soil Erosion Control and Agroforestry Program
SRID	Statistical Research and Information Department
SWC	Soil and Water Conservation
UNEP	United Nations Environment Program
UNSO	United Nations Sudano–Sahelian Office
USAID	United States Agency for International Development

WASWC	World Association of Soil and Water Conservation
WECARD	West and Central African Council for Agricultural Research and Development en anglais

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CHAPTER ONE

INTRODUCTION

1.1 Background

Soil erosion is one of the most important and challenging problems facing farmers and natural resource managers worldwide (Lal, 1995; Stroosnijder, 1995). As a result of soil erosion, vast areas of once fertile lands have been rendered unproductive. Land is one of the most important assets for people throughout the world especially for the rural and urban dwellers whose life basically relies on agriculture. However, this valuable property is being degraded due to soil erosion and nutrition depletion (Amsalu and Graaff, 2007).

Different soil and water conservation (SWC) measures have been developed and promoted to minimise soil erosion (Thomas *et al*., 1997; AHI, 2000). These SWC measures are expected to reduce soil loss due to runoff, retain more moisture and nutrients; with resulting increase in crop yield. However, there is little information to what extent these SWC measures achieve the expectations (physical effectiveness) so as to enable proper planning and convincing of farmers and farming communities to invest in SWC. Land is an important resource for Ghana both in economic and social terms. The economy of the country is largely agriculture-based and the sector contributes 38% of the GDP, around 75% of the country's export earnings and 60% of the employment (World Bank, 2006).

Food production in Ghana is concentrated in the savannah and forest zones with the three northern regions producing a substantial portion of the national output. The three regions have the potential for increased agricultural production, to realize this potential there is the need to address the deteriorating soil conditions. Against this background, governmental and non-governmental organizations in Northern Ghana are engaged in promoting soil and water conservation practices, such as grass stripping, composting, stone and soil bunds, among farmers in the area. But adoption of the practices among farmers is believed to be low (Nkegbe *et al.*, 2011).

In Ghana, both governmental and non-governmental organizations have in the past introduced a number of SWC techniques, but the adoption rates are not better than what prevails elsewhere in the continent. Mindful of the fact that, most agricultural growth in the country has been attributed to land area expansion as opposed to yield increases (MoFA, 2007). Improving productivity through dissemination of yield-enhancing technologies have become the focus for Ghana's Ministry of Food and Agriculture. Land degradation is affecting all parts of the country. However, the northern regions situated within the Guinea and Sudan Savannas are the most vulnerable zones. Specifically the Upper East Region is the most degraded area of the country (World Bank, 2006).

1.2 Problem Statement and Justification

Soil is a key natural resources on earth. Though soil is a renewable natural resource, it can become finite with the passage of time, through erosion. In the northern regions of Ghana, soil erosion is a problem as a result of poor soil management. The contributing factors include agricultural practices of conventional agriculture e.g. ploughing. There is a universal acceptance that such agricultural practices promote soil erosion. The main on-site impact of soil erosion is soil loss and reduction in soil quality which results from the loss of the nutrient-rich top soil, and the reduced water-holding capacity of the eroded soils. SWC measures are therefore very essential as soil erosion has become an issue of growing concern.

1.3 Research Objectives

The study was undertaken to determine the effect of soil and water conservation measures (contour farming, half-moon and contour ridges) on yield components and yield of cowpea and maize, in six selected communities in the Northern and Upper East Regions of Ghana.

The study was specifically undertaken to:

1. Assess the effectiveness of contour farming, half-moon and contour ridges on soil moisture conservation under cowpea and maize cultivation

2. Assess the effectiveness of contour farming, half-moon and contour ridges as soil and water conservation measure on growth and yield of cowpea

3. Assess the effectiveness of contour farming, half-moon and contour ridges as soil and water conservation measure on growth and yield of maize

4. Identify farmers' perception and awareness of erosion processes and SWC measures as a land management practice

CHAPTER TWO

LITERATURE REVIEW

2.1 Soil Erosion by Water

Soil erosion is a naturally occurring process that affects all landforms. In agriculture, soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage. Erosion, whether it is by water, wind or tillage, involves three distinct actions – soil detachment, movement and deposition. Topsoil, which is high in organic matter, fertility and soil life, is relocated elsewhere where it builds up over time or where it fills in drainage channels. Soil erosion reduces cropland productivity and contributes to the pollution of adjacent water courses, wetlands and lakes (Ritter and Eng, 2012).

Soil erosion by water is one of the most important forms of land degradation that threatens continued and sustained agricultural production in Ghana. The most severely affected areas are the three Northern Savanna Regions, particularly the Upper East Region, where large tracts of land have been destroyed by water leading to soil depth reduction, soil fertility decline and siltation of rivers and reservoirs (Adwubi *et al.*, 2009). About 80% of the populations live in the rural areas with agriculture as their major economic activity (Birner *et al.*, 2005). Sustainable agricultural production also depends on productive soils, but the land resources of Ghana for that matter the Northern Regions, particularly the soils, are being degraded as a result of both natural and anthropogenic factors. Soil degradation in its several forms is evident in all the three Northern regions of Ghana and therefore a major constraint to the attainment of the desired growth rate in the agricultural sector (Asiamah *et al.*, 2000).

The implications of soil erosion by water extend beyond the removal of valuable topsoil. The loss of soil reduces depth, water and nutrient storage capacities of the soil. The reduction in moisture reduces the soil's potential to sustain plant growth, exposes the plants to frequent and severe water stress which ultimately results in reduced crop yields. Many of the soils have predominantly light-textured surface horizons and extensive areas of shallow concretionary and rocky soils with low water and nutrient holding capacities and limited capacity for agriculture (Quansah *et al.*, 2000).

Surveys carried out in the Northern Regions indicated that, the area of degraded land in the region increased by about 200% between 1973 and 2006. As a result, grain production per head decreased from about 245 kg capita^{-1} year^{-1} in 1965 to 200 kg capita^{-1} year^{-1} in 1975, 156 kg capita^{-1} year^{-1} in 1985 and below 100 kg capita^{-1} year^{-1} in 2008 (MoFA, 2008).

A major non biophysical effect of land degradation in Northern Ghana is migration of farmers from degraded regions to rural areas of the Brong Ahafo Region that have more fertile agricultural soil unlike the impoverished agricultural lands at the origin of migrants as evidenced by low crop yields coupled with unreliable rainfall resulting in food insecurity problems. Any further worsening of desertification in Northern Ghana would in no doubt affect the economy of Ghana adversely as much of the food and animal products come from these regions (Kwarteng, 2002).

2.2 Effects of Soil Erosion by Water

The effect of erosion may be on-site or off-site. The off-site impacts of soil erosion by water are not always as apparent as the on-site effects.

2.2.1 On-site effects

In the process of physical removal of productive topsoil, soil erosion results in immediate on-site effects. On-site effects are those that happen at the site where erosion occurs. The on-site damages or effects therefore include soil structure degradation, increased erodibility, surface crusting and compaction. Crop emergence, growth and yield are directly affected by the loss of natural nutrients and applied fertilizers. Seeds and plants can be disturbed or completely removed by the erosion. Organic matter from the soil, residues and any applied manure, is relatively lightweight and can be readily transported off the field. Pesticides may also be carried off the site with the eroded soil. Soil quality, structure, stability and texture can be affected by the loss of soil. The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture. Textural changes can in turn affect the water-holding capacity of the soil, making it more susceptible to extreme conditions such as drought (Adwubi *et al.,* 2009).

2.2.2 Off-site effects

The off-site impacts of soil erosion by water are not always as apparent as the on-site effects. Eroded soil, deposited down slope, inhibits or delays the emergence of seeds, buries small seedlings and necessitates replanting in the affected areas. Also, sediment can accumulate on down-slope properties and contribute to road damage. Sediment that reaches streams or watercourses can accelerate bank erosion, obstruct stream and drainage channels, fill in reservoirs, damage fish habitat and degrade downstream water quality. Pesticides and fertilizers, frequently transported along with the eroding soil, contaminate or pollute downstream water sources, wetlands and lakes. Because of the potential seriousness of some of the off-site impacts, the control of "non-point" pollution from agricultural land is an important consideration (Ritter and Eng, 2012).

Soil leaving the boundary of the field due to erosion and entering other fields will have negative effects on the present and future crop productivity of the plots downstream. The negative effects include crop burial by sediment deposition, crop damage by increased frequency and depth of floods and water lodging due to accumulation of overland flow in depressions. The future productivity of crops will also be affected due to long-term changes in soil quality as a result of water lodging and sediment deposition in depressions (Adwubi *et al.*, 2009).

Siltation of water reservoirs used for irrigation, hydroelectric power, and other purposes, is among the negative off-site effects of soil erosion that attracted more research and policy attention. Relatively, more quantified research information has become available on the cost of damage to water reservoirs caused due to siltation than other off-site effects of soil erosion. This might be due to the relative ease of measurement and assignment of economic value to the damage, or due to its immediate impact on the day-to-day life of society (Enters, 1998a).

2.3 Factors Affecting Soil Erosion by Water

The rate and magnitude of soil erosion by water is controlled by the following factors; rainfall intensity and runoff, soil erodibility, slope gradient and length, vegetation and conservation measures.

2.3.1 Rainfall intensity and runoff

Both rainfall and runoff factors must be considered in assessing a water erosion problem. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter can be easily removed by the raindrop splash and runoff water; greater raindrop energy or run-off amounts might be required to move the larger sand and gravel particles. Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short duration, high-intensity thunderstorms. Although the erosion caused by long-lasting and less intense storms is not as spectacular or noticeable as that produced during thunderstorms, the amount of soil loss can be significant, especially when compounded over time. Runoff can occur whenever there is excess water on a slope that cannot be absorbed into the soil or trapped on the surface. The amount of runoff can be increased if infiltration is reduced due to soil compaction, crusting or freezing. Runoff from the agricultural land may be greatest during periods when the soils are usually saturated and vegetative cover is minimal (Abegunde *et al.*, 2006).

2.3.2 Soil erodibility

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils. Tillage and cropping practices which lower soil organic matter levels, cause poor soil structure, and results of soil compaction contribute to increases in soil erodibility (Ritter and Eng, 2012). Decreased infiltration and increased runoff can be a result of compacted subsurface soil layers. A decrease in infiltration can also be caused by a formation of a soil crust, which tends to "seal" the surface. On some sites, a soil crust might decrease the amount of soil loss from sheet or rain splash erosion. However, a corresponding increase in the amount of runoff water can contribute to greater rill erosion problems (Olori, 2006).

Past erosion has an effect on a soil's erodibility for a number of reasons. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were, because of their poorer structure and lower organic matter. The lower nutrient levels often associated with sub-soils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil (Abegunde *et al.,* 2006).

2.3.3 Slope gradient and length

Naturally the steeper the slope of a field, the greater the amount of soil loss from erosion by water. Soil erosion by water also increases as the slope length increases due to the greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential due to increased velocity of water which permits a greater degree of scouring (Abegunde *et al.,* 2006).

2.3.4 Vegetation

Soil erosion potential is increased if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of surface runoff and allows excess surface water to infiltrate. The erosion-reducing effectiveness of plant and/or residue covers depends on the type, extent and quantity of cover (Abegunde *et al.,* 2006). Vegetation and residue combinations that completely cover the soil, and which intercept all falling raindrops at and close to the surface are the most efficient in controlling soil (e.g. forests, permanent grasses). Partially incorporated residues and residual roots are also important as these provide channels that allow surface water to move into the soil (Ritter and Eng, 2012).

The effectiveness of any crop, management system or protective cover also depends on how much protection is available at various periods during the year, relative to the amount of erosive rainfall that falls during these periods. In this respect, crops which provide a food, protective cover for a major portion of the year (for example, alfalfa or winter cover crops) can reduce erosion much more than can crops which leave the soil bare for a longer period of time (e.g. row crops) and particularly during periods of high erosive rainfall (spring and summer). However, most of the erosion on annual row crop land can be reduced by leaving a residue cover greater than 30% after harvest and over the winter months, or by inter-seeding a forage crop (e.g. red clover) (Ritter and Eng, 2012).

2.3.5 Conservation measures

Certain conservation measures can reduce soil erosion by both water and wind. Tillage and cropping practices, as well a land management practices, directly affect the overall soil erosion problem and solutions on a farm. When crop rotations or changing tillage practices are not enough to control erosion on a field, a combination of approaches or more extreme measures might be necessary. For example, contour plowing, strip cropping, or terracing may be considered (Ritter and Eng, 2012).

2.4 Soil and water conservation (SWC) measures

According to AfDB (2009) SWC practices represent all the practices that are implemented with the aim of preventing net runoff from a given cropped area and rather holding rain water and prolonging the time for infiltration. Usually SWC is understood as the implementation of agricultural measures on the field level (e.g. contour ploughing, reduced tillage, terracing). However, SWC also comprises steps at the political, economic and juridical levels, given the fact that the main driving forces are created on these levels (Boardman *et al.,* 2003; Bridges *et al.,* 2001; Hannam and Boer, 2002).

Hannam and Boer (2002) defined the aim of SWC as obtaining the maximum sustained level of production from a given area of land whilst maintaining soil loss below a threshold level which, he said, theoretically permits the natural rate of soil formation to keep pace with the rate of soil erosion. This definition contains two specific aims that can be used in an economic analysis. One is to find a long term maximum level of soil use that is not threatened by over-exploitation and nutrient mining. The other contains the idea of a threshold rate of soil use or depletion that can be adjusted to the natural rate of soil formation.

Previous focus of SWC practices was solely on soil erosion control as opposed to building soil's resilience to runoff, nutrient depletion, soil cover as well as soil moisture conservation (Liniger *et al.,* 2004). Therefore most of the SWC practices have had limited adoption by farmers as they do not see immediate tangible benefits such as increased crop yields arising from implementation of the practices. A sustainable SWC practice should be able to improve the soil's physical and chemical properties and build adequate soil cover. These in turn enhance the soil's ability to resist erosion at the same time providing adequate moisture and nutrients for increased crop yields.

Soil quality and soil fertility are the major determinants of soil resilience to degradation and crop yields. Several studies have indicated that SWC practices directly or indirectly influence soil quality as well as soil fertility (Tesfay *et al.,* 2012b). SWC practices improve soil structure and soil porosity, increase infiltration and soil hydraulic conductivity, and consequently increase soil water storage. Some SWC practices also improve soil chemical properties. Tesfay *et al.* (2011) reported increased build-up of organic matter after implementation of SWC measures. Organic matter not only plays a central role in improving soil structure and porosity but also acts as a source of plant nutrients thus improving soil fertility.

2.4.1 Contour farming as a soil and water conservation measure

Contour farming is the practice of tilling sloped land along lines of consistent elevation in order to conserve rainwater and to reduce soil losses from surface erosion. These objectives are achieved by means of furrows, crop rows, and wheel tracks across slopes, all of which act as reservoirs to catch and retain rainwater, thus permitting increased infiltration and more uniform distribution of the water. Farming on the contour creates small ridges that slow runoff water, and it increases the rate of water infiltration, reduces the hazard of erosion, and redirects runoff from a path directly downslope to a path around the hill-slope (Anschutz *et al.,* 1997). Farming on the contour rather than up and down the slope reduces fuel consumption and is easier on equipment. Contour farming is often used in combination with other practices, such as terraces, water- and sediment-control basins, and strip cropping. Irregular slopes may require more than one key contour line. Some fields may be too steep and/or irregularly shaped for contour farming.

In contour farming, all tillage and planting operations should be parallel to the key contour line. Contour farming can reduce soil erosion by as much as 50% compared to farming up and down hills. It promotes better water quality by controlling sedimentation and runoff and increasing the rate of water infiltration. Minimum and maximum row grade, ridge height, slope lengths and stable outlets must be determined. Obstruction removal and changes in field boundaries and shape should be considered to improve the effectiveness of the practice and ease of farming operations. Agricultural operations with slopes exceeding 10% will find this practice less effective. Rolling topography having a high degree of slope irregularity is not well suited to contour farming (Anschutz *et al.*, 1997).

The distance between contour lines depends on the steepness of the slope. It could be as little as 8m or as much as 30m. The steeper the slope, the closer the contour barriers have to be to prevent erosion. It also depends upon the amount of rain that falls, and on what you are going to do with the land. As a guideline, contour lines should be 3-4m apart on a steep slope, and 5-6m apart on a moderate slope. Contour ploughing is successful on slopes with a gradient of less than 10%. On steeper slopes contour ploughing should be combined with other measures, such as terracing or strip cropping (Anschutz *et al.,* 1997). The fields should have an even slope, since on very irregular slopes it is too time-consuming to follow the contours when ploughing. Contour farming can be implemented at the time the field is being prepared for farming.

Advantages

- Reduces runoff and soil erosion.
- Reduces nutrient loss.
- When using animal draft, ploughing is faster, since the equipment moves along the same elevation.

Limitations

- Improperly laid out contour lines can increase the risk of soil erosion.
- Labor-intensive maintenance.
- If the soils are heavy with low infiltration capacity, a lot of water might collect, increasing the chance of braking.

2.4.2 Half-moon as a soil and water conservation measure

Half-moon, also known as semi-circular bunds are small earth bunds in the shape of a semi-circle with the tip of the bunds on the contour. They are used to harvest water flowing down a slope for crops uptake. The size of the bunds varies, from small structures with a radius of 2m to very large structures with a radius of 30m depending on what crop or plant is grown. Crops such as sorghum, millet and cowpeas can be planted in the lower portion of the half-moons, using conservation agriculture techniques. Large structures are used for rangeland rehabilitation and fodder production. The entire enclosed area is planted. When used for tree growing, the runoff water is collected in an infiltration pit, at the lowest point of the bund, where the tree seedlings are planted (Anschutz *et al.*, 1997).

Bunds are constructed by digging out earth from within the area to be enclosed and piling it up to form the bund. They should be constructed in layers of 10-15cm, with each layer compacted before the next is added to ensure that they remain stable. They are easy to construct and reduce soil erosion. The bunds are arranged along a contour line in a staggered arrangement and gap is left between neighbouring structures so that water, which spills round the ends of the upper hills, are caught by those lower down (Anschutz *et al.,* 1997). In larger structures stone spillways can be constructed in the bunds to cope with excess runoff from the slopes above. But, when large amounts of runoff can be expected often, the structures have to be protected by digging a diversion ditch. Semi-circular bunds are suitable on gentle slopes (normally below 2%) and uneven terrain in areas with annual rainfall of 350-700mm. The soils should not be too shallow or saline.

Advantages

- Easy to construct.
- Suitable for uneven terrain.
- Increases soil moisture.
- Reduces erosion.

Limitations

- Difficult to construct with animal draft.
- Requires regular maintenance.
- Due to the semi-circular form, mechanized construction is not easy.

2.4.3 Contour ridges as a soil and water conservation measure

Contour ridges, sometimes called contour furrows consist of parallel, or almost parallel, earth ridges approximately on the contour at a spacing of between one and two metres. Soil is excavated and placed downslope to form a ridge, and the excavated furrow above the ridge collects runoff from the catchment strip between ridges. Like other contour barriers, they slow down water flow and catch sediment before it is washed away. Small earth ties in the furrow may be provided every few metres to ensure an even storage or distribution of runoff. Crops are planted in between the ridges (furrow) and not on the ridges (Anschutz *et al.,* 1997).

Through their shape, soil moisture is increased under the ridge and the furrow, in the vicinity of plant roots. The distance between the ridges depends on the slope gradient and the size of the catchment area desired (Anschutz *et al.,* 1997). The ridges are spaced at intervals of 1.5m. Small cross-ties in the furrows are constructed at regular intervals and at right angles to the ridges, to prevent flow of runoff water through the furrows (erosion) and to ensure evenly spread storage of runoff (Anschutz *et al.,* 1997).

Advantages

- The runoff yield from the short catchment length is very efficient.
- Labour requirements are relatively low.
- Contour ridges are easy to make using hand tools.
- They are easy to manage for small farmers.

Disadvantages

- Good results on silty loam to clay loam soils.
- On heavier, more clayey soils they are less effective because of the lower infiltration rate.
- Heavy and compacted soils may also be a constraint to construction by hand.
- Topography must be even. Areas with rills or small depressions are less suitable due to the uneven distribution of water.

2.4.4 Farmers practice (conventional tillage)

Conventional tillage is the sequence of operations traditionally or most commonly used in a given geographic area to produce a given crop. The operations used vary considerably for different crops and in different regions. Conventional tillage unlike the other soil and water conservation measures is often not conservational to soil and water. There is much discussion about the effect of tillage on soil moisture conservation (Anschutz *et al.,* 1997). Tillage is good for water infiltration and root penetration, as the soil is worked into clods. However, this is only true for stable soils. If the soil is less stable, the clods will disappear rapidly when it rains. Tillage is required on badly degraded soils or for those that undergo severe hardening during the dry season (Anschutz *et al.,* 1997).

However, repeated cultivation may cause a compacted soil layer to form at the bottom of the tilled layer (called a ’plough-pan’, or ’hoe-pan’ etc.). Plant roots cannot penetrate into this layer and the water storage capacity of the soil is reduced. In this case, when the clogged layer is several tens of centimetres below the surface, subsoiling is necessary to increase infiltration (Anschutz et al., 1997). Some soils become crusted over the surface when it rains, especially soils containing much clay and silt. This leads to a low infiltration rate and a high rate of runoff. In this case, with crusted soils, when the soil pores are clogged in the first few millimetres or centimetres, hoeing or superficial ploughing is sufficient to break up the crust and let the water infiltrate (Anschutz *et al.,* 1997).

Advantages

- Does not require contour lines
- Not labour intensive to maintain

Disadvantages

- It can encourage soil erosion and more rapid decay of soil organic matter
- It may allow more moisture to escape through evaporation

2.5 Effects of Soil and Water Conservation (SWC) Measures on Crop Yield

The increased yields observed in SWC practices were attributed not only to increased water conservation, but also to improved soil quality especially increased build-up of organic matter as a result of stubble residue retention and minimum tillage. It has also to be mentioned here that crop yield response to SWC may be influenced by other factors including crop requirements, soil characteristics as well as climate (Giller *et al.*, 2009). This implies that for the same SWC practices, it is possible to realise mixed yield responses due to differences in crop, soil and climate. This therefore calls for exhaustive studies on SWC practices to suit a given crop, soil and climate.

2.6 Cowpea Production

Cowpea is a dicotyledonous plant belonging to the family Fabaceae and sub-family, Fabiodeae. It is grown extensively in the low lands and mid-altitude regions of Africa (particularly in the dry savanna) sometimes as sole crop but more often intercropped with cereals such as sorghum or millet (Agbogidi, 2010). World production of cowpea was estimated to be 2.27 million tons of which Nigeria produces about 850,000 tones (FAO, 2002; Adaji *et al.*, 2007).

Cowpea is of major importance to the livelihoods of millions of relatively poor people in less developed countries of the tropics (FAO, 2002). Islam *et al.* (2006) emphasized that all parts of the plant used as food are nutritious providing protein and vitamins, immature pods and peas are used as vegetables while several snacks and main dishes are prepared from the grains.

2.7 Maize Production

Maize (*Zea mays*) is a tall, monoecious annual grass with overlapping sheaths and broad conspicuously distichous blades. Plants have staminate spikelets in long spike-like racemes that form large spreading terminal panicles (tassels) and pistillate inflorescences in the leaf axils, in which the spikelet occur in 8 to 16 rows, approximately 30cm long, on a thickened, almost woody axis (cob). The whole structure (ear) is enclosed in numerous large foliaceous bracts and a mass of long styles (silks) protrude from the tip as a mass of silky threads. Pollen is produced entirely in the staminate inflorescence and ear, entirely in the pistillate inflorescence. Maize is wind pollinated and both self and cross pollination is usually possible (FAO, 2008; Morris *et al.*, 1999)

2.8 Farmers Perception about Soil and Water Conservation (SWC) Measures

Though much studies have not been done on farmers' perception about SWC and factors affecting their decisions in Ghana; Northern Ghana especially, literature of studies elsewhere indicate that, farmers have long recognized that land cannot be used without limit and have also perceived a decline in soil productivity, and continued water shortages in low rainfall areas. They consider these problems to be a natural course, which cannot be avoided (Siachinji-Musiwa, 1999), therefore necessitating some action on their part.

The traditional farming systems that farmers have previously employed to sustain their productivity cannot any longer effectively work due to population pressure. It is now evident that in provinces such as Central and Southern Provinces where yield of maize used to be around 2.4 metric t ha^{-1} in 1981, the typical yield now is about 1.5 metric t ha^{-1} (Mulenga, 2003). In Ghana, both governmental and non-governmental organizations have introduced a number of soil and water conservation (SWC) techniques, but adoption rates are lower than what prevails elsewhere on the continent.

2. 9 Economics of SWC Measures

Economic use of soil resources is a fundamental concern because land is an essential input in agriculture, in the sense that no output will be produced without its use. This is particularly true for Africa and many other developing countries where non-labor inputs in agriculture are negligible and agricultural land is the critical resource and the basis for survival of the vast majority of the population (Barbier, 2003). Agriculture in these countries is not only an economic activity but also a way of life. Thus, agricultural land is a cornerstone upon which the welfare of society is built. In the process of using land, farmers expose the land to various forms of degradation - physical, chemical, and biological. As a result, this crucial resource is under continuous threat and its long-term productive potential is being impaired. In economic terms, land degradation causes a decline in the attributes of land in relation to specific functions of value (Bekele, 2003).

The purpose of soil conservation is not merely to preserve the soil but to maintain its productive capacity while using it (Troeh *et al.*, 1999). Therefore, decisions on conserving soil erosion and rehabilitating degraded land depend on the costs relative to the value of output or environmental benefit expected. Since the value of fertile soil is not infinite relative to other human needs, it is not worth preventing soil erosion unless the benefits gained exceed the costs incurred in conservation activities (Barbier and Bishop, 1995). Therefore, farmers will not be interested in investing in conservation and bearing associated risks unless they perceive a significant threat posed on productivity due to soil erosion and expect economic gains from conservation practices.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was carried out on-station and on-farm. The on-station work was done in Tamale in the Northern Region and on-farm in selected communities in the Northern and Upper East Regions of Ghana.

3.1.1 Northern Region

The Northern Region (Fig. 3.1) covers an area of 70,384km^2, making it the largest region in terms of landmass in Ghana (GSS, 2010). It occupies about 30% of the total land area of the country and lies between latitudes 9° 10′ N and 9° 20′ N and longitudes 0° 22′ W and 0° 34′ W. It is approximately 180 m above sea level. The region shares international borders with Cote d'Ivoire to the West and Togo to the East. It borders Brong Ahafo and Volta Regions to the south, and the Upper East and Upper West Regions to the North-East and North-West of Ghana respectively.

The climate of the region is relatively dry, with a single rainy season that begins in May and ends in October with a mean annual rainfall of about 1100 mm. The dry season starts in November and ends in April/May with maximum temperatures occurring towards the end of the dry season (April-May) 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 temperature in the region. Humidity, however, is usually low and mitigates the effect of the daytime heat.

The vegetation cover is mainly Guinea Savanna with grasses interspersed with short trees. The vegetation is however dense in the southern portion near the Brong Ahafo region, and thins out northwards towards the Upper Regions. Common among the trees are acacia (*Senegalia greggii*), baobab (*Adansonia digitata*), sheanut (*Vitelleria paradoxa*), dawadawa (*Parkia biglobosa*), mango (*Mangifera indica*) and neem (*Azadirachta indica*). The region's soils are mainly, savanna ochrosols and groundwater lateritic soils. These soils favour the production of yam (*Dioscorea spieces*), cereals such as maize (*Zea mays*) and guinea corn (*Sorghum bicolor*).

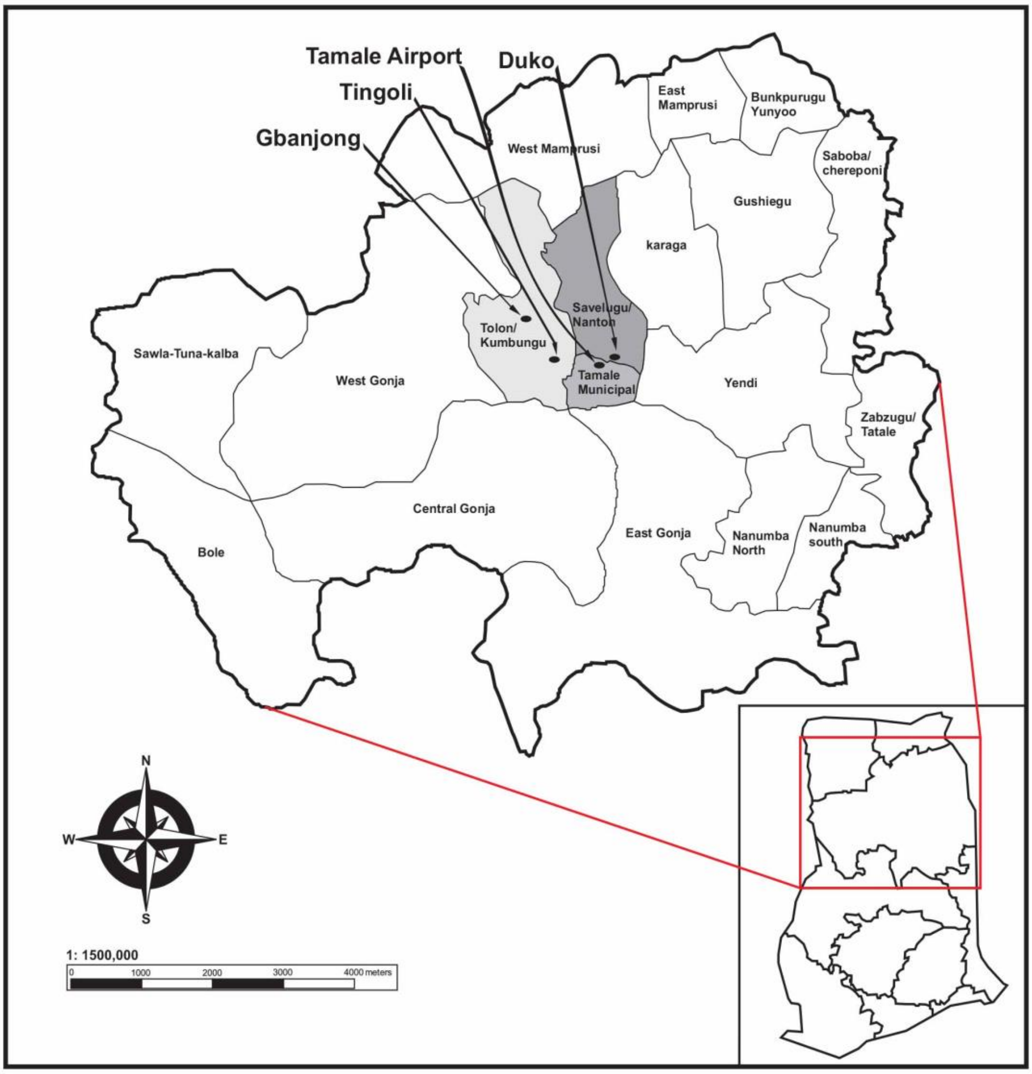


Fig. 3.1: Map of Northern Region of Ghana showing the districts and the study sites

Description of communities

The on-station experiment was carried out in the Tamale Airport area. The on-farm experiment in the Northern Region was carried out at Duko, Tingoli and Gbanjong. The Tamale Airport which is located in Tamale metropolis, lies on latitude 9^{o} 33′ N and longitude 0^{o} 51′ W. Duko is on latitude 9^{o} 34′ N and longitude 0^{o} 49′ W in the Savelugu District. Tingoli and Gbanjong are both in the Tolong District with Tingoli located on latitude 9^{o} 23′ N and longitude 1^{o} 00′ W and Gbanjong on latitude 9^{o} 27′ N and longitude 1^{o} 60′ W.

3.1.2 Upper East Region

Upper East Region (Fig. 3.2) is located in the north-eastern corner of the country between latitudes 10^{o} 15′ N and 11^{o} 10′ N and longitudes 0^{o} W and 1^{o}40′ W and covers an area of 8,842 km^2 (i.e. 3.7% the total land area of Ghana). It is bordered to the north by Burkina Faso, east by the Republic of Togo, west by Sissala District in Upper West Region and the south by West Mamprusi District in Northern Region. The land is relatively flat with few hills to the East and Southeast.

The climate is characterized by one rainy season from June/July to October. The mean annual rainfall during this period is about 900 mm (MoFA, 2011). The dry season from November to May is characterized by cold, dry and dusty harmattan winds. Humidity is very low making the daytime temperature high but less uncomfortable (Liebe, 2002).

The natural vegetation is that of the savannah woodland characterised by short scattered drought-resistant trees and grasses that get burnt by bushfire or scorched by the sun during the long dry season (Needham, 1993). The most common economic trees are the sheanut (*Vitelleria paradoxa*), dawadawa (*Parkia biglobosa*), baobab (*Adansonia digitata*) and acacia (*Senegalia greggii*).

The region's soil is mainly developed from granite rocks. It is shallow and low in fertility, weak with low organic matter content, and predominantly coarse textured. Erosion is a major challenge. Low land areas have soils ranging from sandy loams to clays. They have higher natural fertility but are more difficult to till and are prone to seasonal waterlogging and floods (Kpongor, 2007).

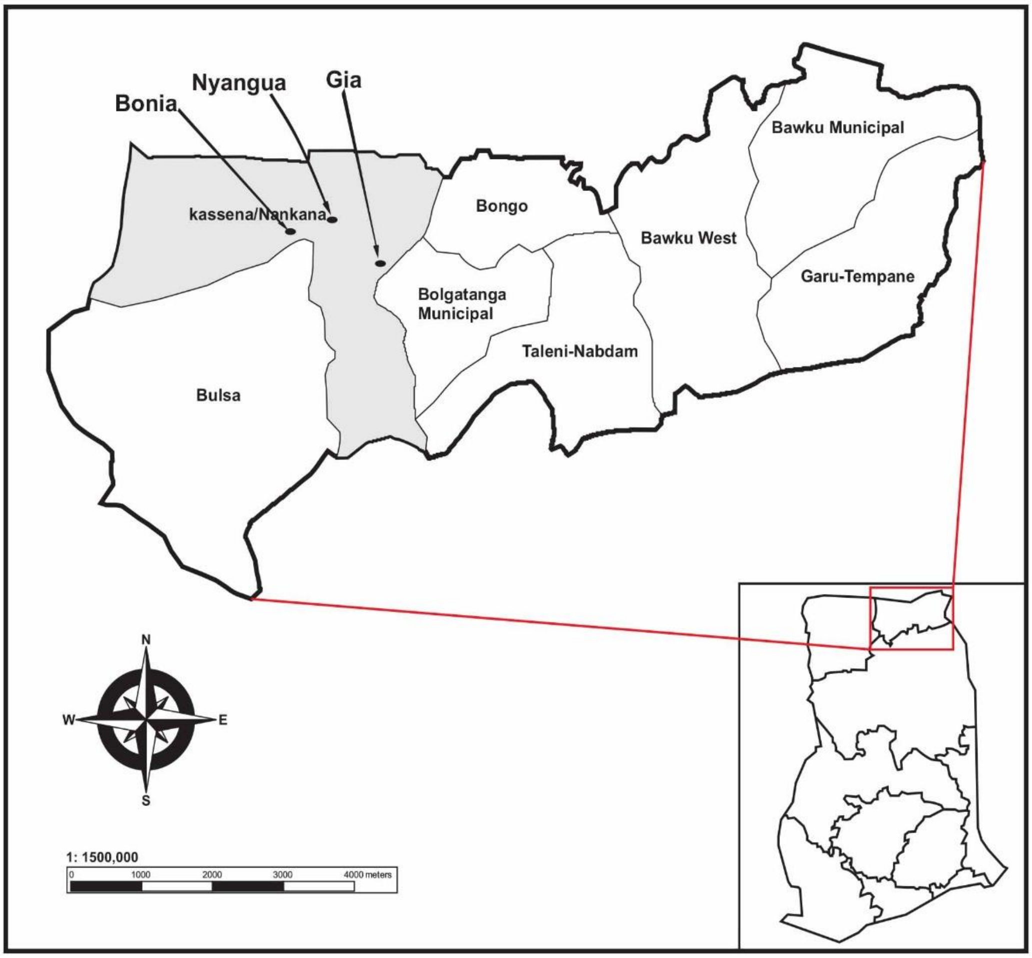


Fig. 3.2: Map of Upper East Region of Ghana showing the districts and the study sites

Description of communities

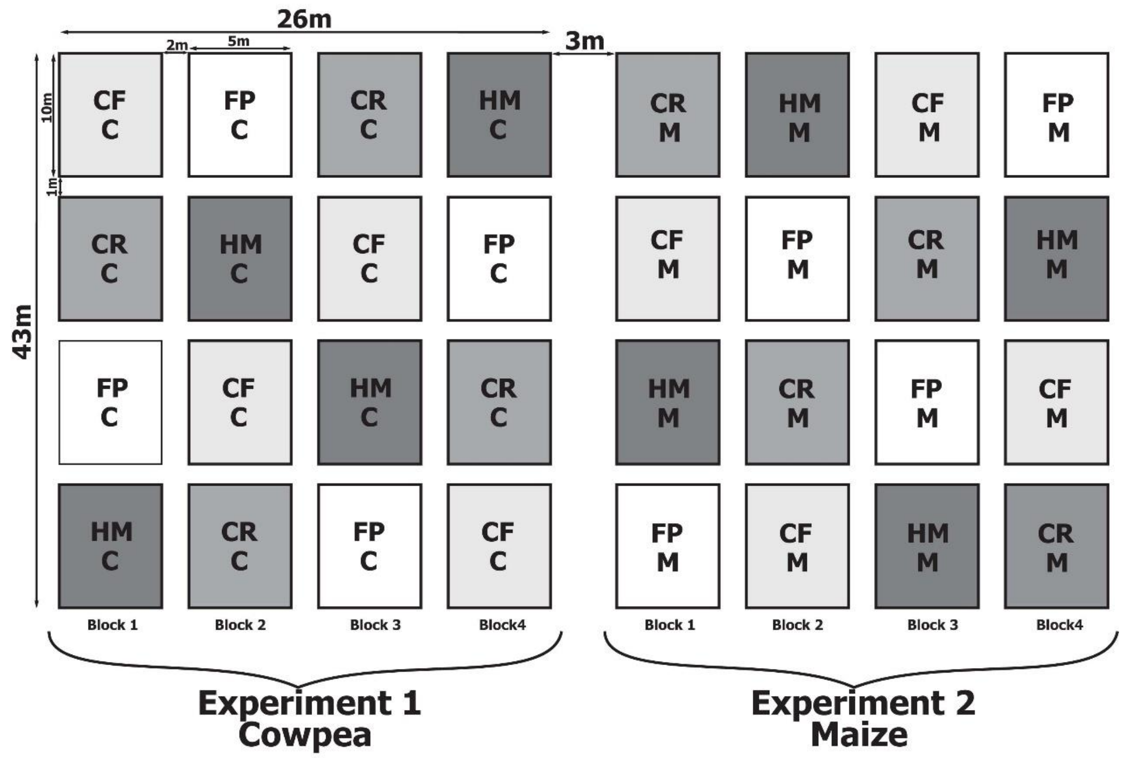
The study communities in the Upper East Region are Bonia, Gia and Nyangua. All the three communities are located in the Kasena Nankana Municipality where Bonia which is a beneficiary of the Tono irrigation project is located at latitude 10^{o} 52′ N and longitude 1^{o} 08′ W. Gia is at latitude 10^{o} 54′ N and longitude 1^{o} 08′ W with Nyangua at latitude 10^{o} 57′ N and longitude 1^{o} 05′ W.

3.2 Experimental Design

The experiment was in two parts at on-station and on-farm. Each category consisted of two experimental units of experiment 1 and 2 for cowpea and maize respectively. The on-station experiment was carried out at the Tamale Airport area in the Northern Region whilst the on-farm experiments were carried out in six communities (Duko, Tingoli, Gbanjong, Bonia, Gia and Nyangua) across the Northern and Upper East Region of Ghana. All the experiments were carried out during the 2014 farming season using the Randomised Complete Block Design (RCBD).

3.2.1 On-station experiment

The on-station experiment consisted of four replications for each experiment (cowpea and maize). Each block measured 5 m × 43 m with 2 m and 1 m alleys between and within replicates respectively. Thus the total dimension of each experimental plot was 26 m × 43 m. Each replicate consisted of four sub plots, each representing a conservation measure [i.e. Contour Farming (CF), Half-Moon (HM), Contour Ridges (CR) and Farmers Practice (FP)]. The field layout is as illustrated in Fig. 3.3.

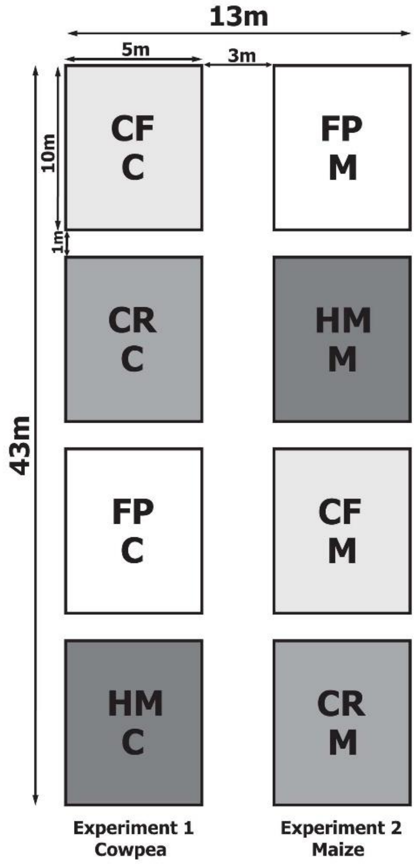


CF – Contour Farming; HM – Half-Moon; CR – Contour Ridges; FP – Farmers Practice; C – Cowpea and M – Maize.

Fig. 3.3: Layout of on-station trial at the Tamale Airport area

3.2.2 On-farm experiment

The on-farm experiment in each community represent a replicate; therefore resulting in three replicates per region. Like the on-station, each replicate measured 5 m × 43 m and consisted of four sub-plots each representing a conservation measure (Figure 3.4).



CF – Contour Farming; HM – Half-Moon; CR – Contour Ridges; FP – Farmers Practice; C – Cowpea and M – Maize.

Fig. 3.4: Layout of on-farm trial in a community

3.2.3 Treatment details

Each of the experiment consisted of three SWC measures as treatments and a farmers practice as a control. The treatments were contour farming, half-moon, contour ridges and farmers practice.

Table 3.1: Treatments for the cowpea trial (Experiment 1)

Treatments	Treatment Combination	Symbols
T1	Contour Farming – Cowpea	CF – C
T2	Half Moon – Cowpea	HM – C
T3	Contour Ridges – Cowpea	CR – C
T4	Farmer's Practice – Cowpea	FP – C

Table 3.2: Treatments for maize trial (Experiment 2)

Treatments	Treatment Combination	Symbols
T1	Contour Farming – Maize	CF – M
T2	Half Moon – Maize	HM – M
T3	Contour Ridges – Maize	CR – M
T4	Farmer's Practice – Maize	FP – M

3.3 Gradient Determination

Prior to the preparation of the land, the slope of each experimental field was determined with the help of a line level. Two 4 m ranging poles with a line (rope) tied between them were held along the slope of the field and the distance between the two poles (AB) noted. The line was tied at point A (2 m mark) of the pole up-slope. A spirit level was then placed in the center of the line to help determine a horizontal level. The line tied at the pole down-slope was then moved upward until the spirit level indicated that the rope was level (at point B). The vertical height difference (VHD) between point A and B was measured and the gradient determined by the formula in equation 1.

$$\text{Slope} = \frac{BC}{AC} \times 100\ \% \qquad [1]$$

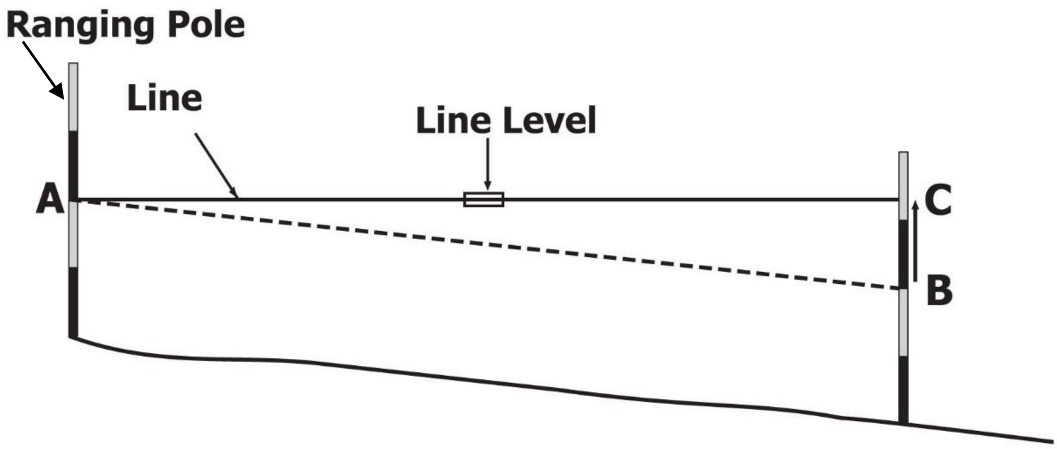


Fig. 3.5: Diagram showing the line level set-up for gradient determination

3.4 Land Preparation and Treatment Implementation

The land was prepared taking into consideration the various conservation measures. The whole experimental plot was first ploughed and harrowed to distribute the soil evenly. The experimental plot was then set out into blocks, with respect to the experimental design. Contour farming and contour ridges required contour lines in their preparations therefore contour lines were determined on the plots.

3.4.1 Setting out contours

Contour lines were determined using the A-frame. One leg of the A-frame was set at one end of the plot and marked with a peg. The other leg of the A-frame was moved by try and error until the next level point is found and marked with another peg. The first leg was swung around and by try and error, the level point is found and pegged. This was repeated until the whole plot was marked.

3.4.2 Preparation of Soil and Water Conservation (SWC) measures

The various conservation measures were prepared on the plots with respect to the plot size, gradient and contours. They were prepared to fit into the plots for the purpose of the experiment.

Contour farming

Contour farming requires that the ploughing/hoeing, sowing and other activities be done along the contours. Ridges were therefore prepared along the contours whiles ensuring that the ridges were parallel to each other and to the contours. This yielded thirteen (13) ridges on each CF plot.

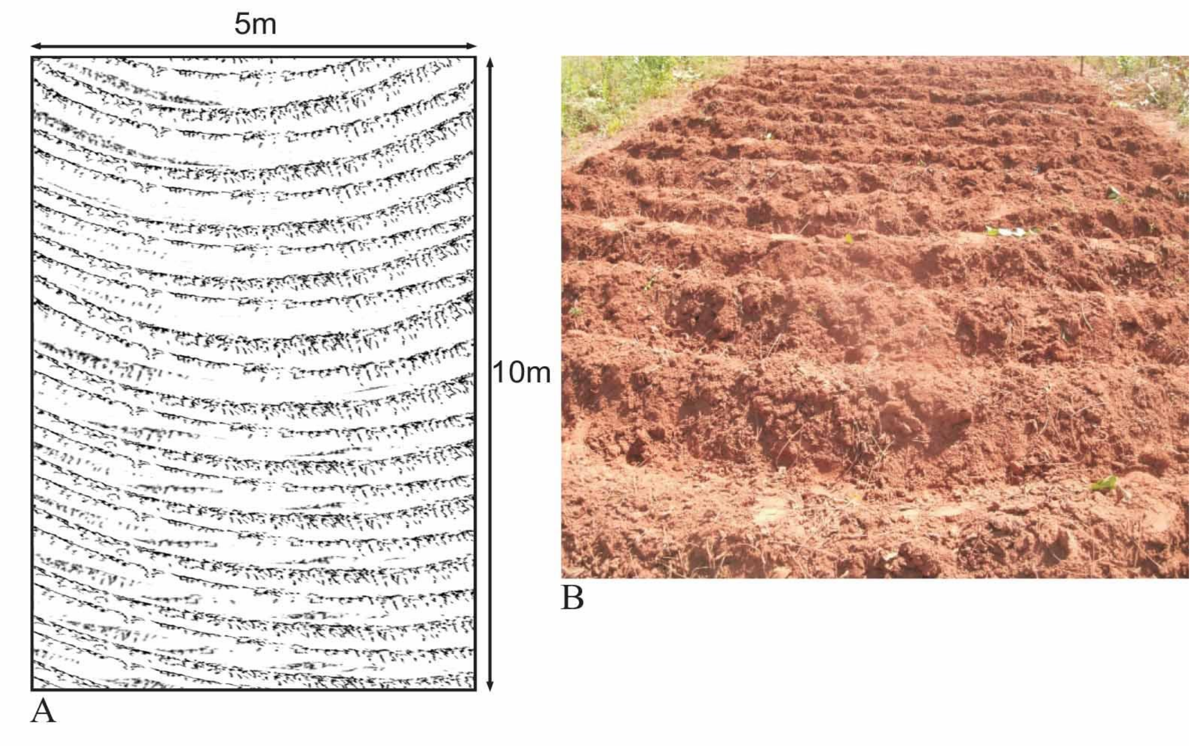


Fig. 3.6: Layout (A) and picture (B) of contour farming

Half-moon

The bunds of the half-moon were laid in staggered rows with their tips on the contours. The semi-circular bunds had a diameter of 2 m and raised to 20 cm with a gap of 1 m left between two neighbouring structures so that run-off water can flow downslope to the next structure. In all, eight semi-circular bunds were prepared on each HM plot.

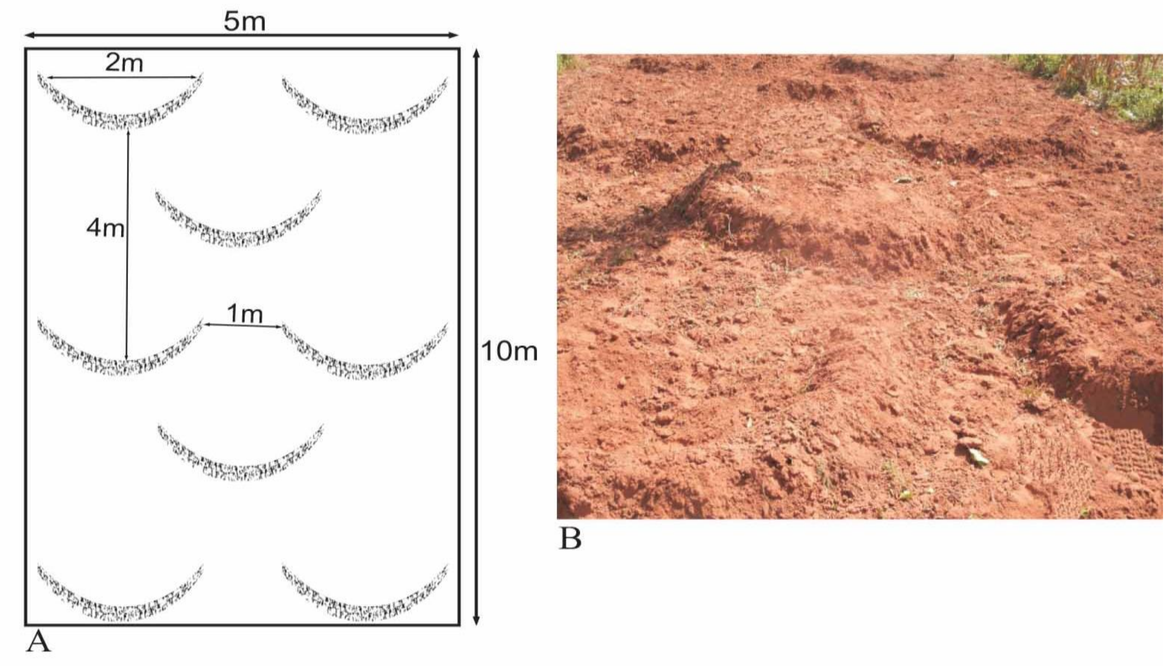


Fig. 3.7: Layout (A) and picture (B) of half-moon

Contour ridges

With the contour ridges, small earth banks parallel to the contour of the slope were constructed at 2 m interval and raised to a height of 20 cm while stretching to the ends of the plot. This resulted in a total of five earth banks on each CR plot.

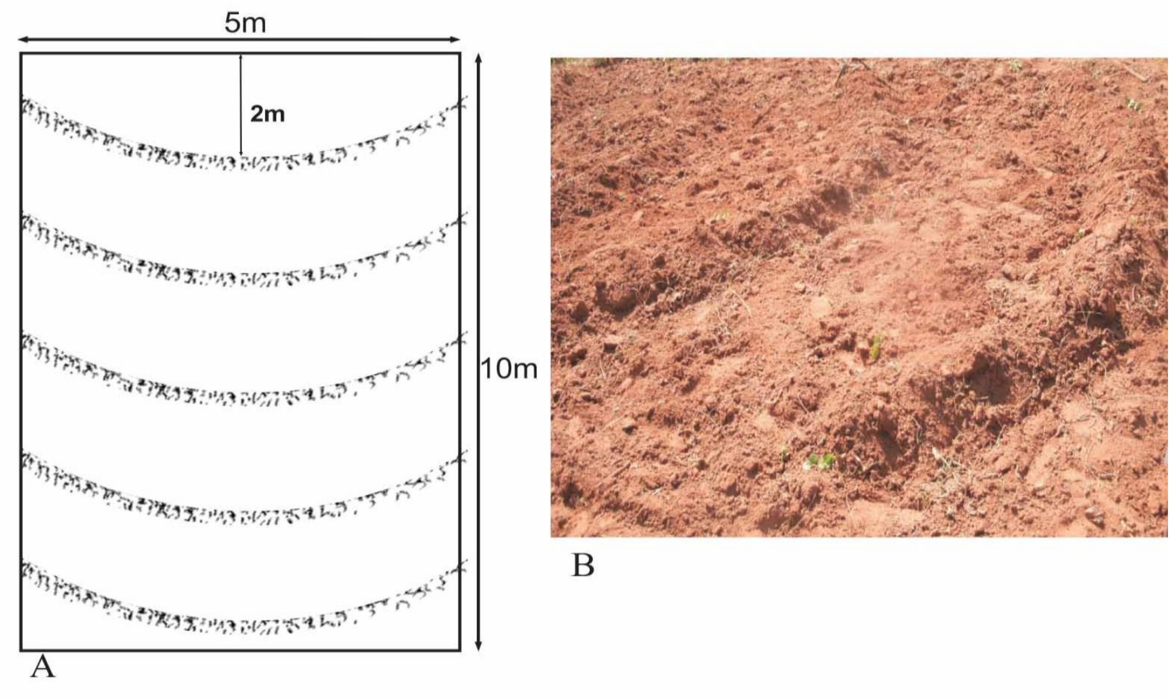


Fig. 3.8: Layout (A) and picture (B) of contour ridges

Farmers practice

The FP plots were prepared taking into consideration the type of conventional tillage practice in the area. The farmers practice is often not conservational to soil and water due to the fact that ploughing is often done along the slope or across the contours. The plots were therefore left bare and flat as they were after harrowing was done.

Fig. 3.9: Picture of farmer's practice

3.5 Cultural Practices

Various cultural practices were performed right from the time of sowing to harvest. These practices were performed uniformly and at the same time interval for the crops in all the replicates across the different communities.

3.5.1 Cultivation

Two crops (cowpea and maize) were cultivated at the on-station and on-farm in the communities of the study. Cultivation methods followed those used locally by the famers in the northern part of the country where hoes were used to form the conservation measures.

Cultivation of cowpea

The *Songotra* cowpea variety with sixty (60) days maturity period was used for the experiment. The cowpea was planted along contours for the contour cultivated plots and along straight parallel rows for the bare plots or non-contour plots. Three seeds were sown per hill and thinned to two plants after two weeks to adjust the population to the desired level. A dibbler was used for the sowing. The distance between rows was 75 cm whilst space between two adjacent hills within a row was 20 cm. The number of rows per plot and number of cowpea plants per row were therefore 13 and 50 respectively. Each plot of cowpea therefore contained 650 cowpea plants.

Cultivation of maize

The *Omankwa* maize variety with ninety (90) days maturity period was used for the experiment. The maize was planted along contours for the contour cultivated plots and along straight parallel rows for the bare plots or non-contour plots. Three seeds were sown per hill and thinned to two plants after two weeks to adjust the population to the desired level. The planting was done with a dibbler. Distance between rows for planting was 75 cm while space between two adjacent hills within a row was 40 cm. The number of rows per plot and number of maize crops per row were therefore 13 and 26 respectively. Each plot of maize therefore contained 338 maize plants.

3.5.2 Weed control

Immediately after sowing, the plots were sprayed with 'Activus 500 EC (Active ingredient: Pendimenthalin 500g/L)' as a pre-emergence weed control measure. Three weeks after planting, the first weeding was done manually with a hoe. The second weeding followed three weeks after the first weeding. There was a third weeding for the maize at three weeks after the second weeding.

3.5.3 Pest control

Due to the vulnerability of the cowpea variety to insects, it was sprayed four times at two weeks interval with 'Cymetox Supper (Dimethoate 250 GMS/LTR + Cypermethrin 30 GMS/LTR)' until it was due for harvest.

3.5.4 Fertilizer application

Both N P K. 15.15.15 and Ammonia fertilizers were applied to the maize crop. The N P K 15.15.15 was applied two weeks after planting at the recommended rate of 5g per hill (i.e. 100 kg ha^{-1}) whilst the Ammonia was done two weeks after the application of the N P K 15.15.15 at the recommended rate of 2.5g per hill (i.e.50 kg ha^{-1}).

3.5.5 Re-shaping of half-moon/ridges

The various conservation measures needed periodic reshaping due to the effects of rainfall and runoff. In view of that, the half-moon/ridges were reshaped on two occasions (i.e. two and six weeks after planting).

3.5.6 Harvesting

Both crops were harvested at maturity. The two middle rows of each plot were harvested for data before the entire crops were harvested. The cowpea was harvested after sixty (60) days whilst the maize was harvested after ninety (90) days.

3.6 Data Collection

3.6.1 Soil chemical properties

Soil samples were taken from the depth of 0-20cm at the beginning of the experiment. The collected samples were air-dried and passed through 2 mm sieve to remove gravels and debris and analysed for the soil pH, O.C, N, P, K, Ca and Mg.

Soil pH

The pH of the soil was determined using a pH meter (1:1 H2O). A 10g soil sample was weighed into a 100 ml beaker. Distilled water (25 ml) was added and a glass rod was used to stir vigorously for 20 minutes. The suspension was allowed to stand for 30 minutes. Calibrated pH meter with buffers at pH 4 and 7 was used to determine the pH value of the partially settled suspension.

Soil organic carbon (OC)

Volumetric method by Walkley and Black (1934) procedure outlined in FAO Fertilizer and Plant Nutrient Bulletin 19 (FAO, 2008) was used to determine the organic carbon concentration. One (1) gram of prepared soil sample was weighed into a 500-ml conical flask. Ten (10) millilitres of 0.1667M $K_2Cr_2O_7$ solution and 20 ml of concentrated H_2SO_4 containing Ag_2SO_4 were added. They were mixed thoroughly and allowed to stand for 30 minutes to complete reaction. The reaction mixture was diluted with 200 ml of water and 10 ml of H_3PO_4. Ten millilitres of NaF solution and 2 mls of diphenylamine indicator were added. It was then titrated against standard 0.5 M $FeSO_4$ solution to a brilliant green colour. A blank without soil sample was run simultaneously.

Calculation:

$$\text{The Percentage of organic C} = 10\ (S - T) \times \frac{0.003}{s} \times \frac{100}{\text{Wt of Soil}} \qquad [2]$$

As 1 g of soil was used, this equation simplifies to % O. C = $\frac{3(S - T)}{S}$ [3]

Where:

S = millilitres of $FeSO_4$ solution required for blank;

T = millilitres of $FeSO_4$ solution required for soil sample;

0.003 = weight of C (1000 ml 0.1667M $K_2Cr_2O_7$ = 3 g C. Thus, 1 ml 0.1667M $K_2Cr_2O_7$ = 0.003 g C).

Organic carbon recovery is estimated to be about 77 percent.

Therefore, the actual amount of organic carbon (Y) will be: percent value of organic carbon obtained × 100/77 or percentage value of organic carbon × 1.3.

Percent organic matter (O.M)

The organic matter of the soil sample was calculated by multiplying the percent organic carbon by a Van Bemmelen factor of 1.724.

Nitrogen (N) concentration

The total nitrogen content of the soil was determined by the modified Kjeldahl method which involves mineral nitrates in the soil by the use of salicylic acid to convert all the nitrates into ammonium salts (Tel and Hagarty, 1984). A 10 g soil was weighed into a 250 ml Kjeldahl digestion flask and 10 mls of distilled water was added to it. Ten millilitres of concentrated H_2SO_4 was added followed by one tablet of selenium and potassium sulphate mixture and 0.10 g salicylic acid. The mixture was made to stand for 30 minutes and heated mildly to convert any nitrates and nitrites into ammonium compounds. The mixture was then heated more strongly (300 – 350 ^{O}C) to digest the soil to a permanent clear colour. The digest was cooled and transferred to a 100 ml volumetric flask and made up to the mark with distilled water. A 20 ml aliquot of the solution was transferred into a tecator distillation flask and 10 mls of 40 % NaOH solution were added and steam from the tecator apparatus allowed to flow into a flask. The ammonium distilled was collected into 10 mls boric acid/ bromocresol green and methyl red solution. The distillate was titrated with 0.01 M HCl solution. A blank digestion, distillation and titration were also carried out as a check against traces of nitrogen in the reagents and water used.

Calculation:

$$\%\mathbf{N} = \frac{(\mathbf{a} - \mathbf{b})\mathbf{x}\ \mathbf{1.4}\ \mathbf{M}\ \mathbf{x}\ \mathbf{V}}{\mathbf{S} \times \mathbf{t}} \qquad [4]$$

Where

a = ml HCl used for sample titration

b = ml HCl used for blank titration

s = weight of soil taken for digestion in grams

M = molarity of HCl

1.4 = 1.4 10^{-3} × 100% (14 = atomic weight of N)

V = total volume of digest

t = volume of aliquot taken for distillation

Phosphorus (P) concentration

Bray's No. 1 method was used to determine the available phosphorus concentration in the soil (Bray and Kurtz, 1945) as outlined in FAO Fertilizer and Plant Nutrient Bulletin 19 (FAO, 2008).

(i) Preparation of the standard curve: A sample (0.2195 g) of pure dry KH_2PO_4 was dissolved in 1 litre of distilled water. This solution contains 50 µg P/ml. This solution was preserved as a stock standard solution of phosphate. Ten millilitres of this solution was taken and diluted to 0.5 litres with distilled water. This solution contains 1 µg P/ml (0.001 mg P/ml). Samples of 0, 1, 2, 4, 6 and 10 ml of this solution were put in separate 25-ml flasks. Five ml of the extractant solution and 5 ml of the molybdate reagent were added to each flask. It was then diluted with distilled water to about 20 ml. One ml of dilute $SnCl_2$ was added to the solution, shaken and diluted to the 25-ml mark. It was allowed to stand for 10 minutes for blue colour development and the blue colour of the solution was read on the spectrophotometer at a wavelength of 660 nm. A graph of absorbance reading against P concentration was plotted.

(ii) Extraction: A 5 g of prepared soil sample was weighed into 100 ml conical flask. Bray's Extractant No. 1 of 50 ml was added to the soil sample, shaken for 5 minutes and filtered.

(iii) Development of colour: A 5 ml aliquot of the filtered soil extract was taken with a bulb pipette into a 25 ml measuring flask and 5 ml of the molybdate reagent was delivered with an automatic pipette. It was diluted to about 20 ml with distilled water, shaken and 1 ml of the dilute $SnCl_2$ solution was added with a bulb pipette. It was filled to the 25 ml mark with distilled water and shaken thoroughly. It was allowed to stand for 10 minutes for blue colour development and read on a spectrophotometer at 660 nm after setting the instrument to zero with the blank prepared similarly but without the soil.

Calculation:

$$P\ (kg/ha) = \frac{A}{1000000} \times \frac{50}{5} \times \frac{2000000}{5} \quad [5]$$

Where:

Weight of soil taken = 5 g;

Volume of extract = 50 ml;

Volume of extract taken for estimation = 5 ml;

Amount of P observed in the sample on the standard curve = A (μg);

Weight of 1 ha of soil down to a depth 22 cm is taken as 2 million kg.

Potassium (K) concentration

Flame photometry method was used to determine the exchangeable potassium concentration in the soil. Standard solutions of 0, 2, 4, 6, 8 and 10 mg/l K were prepared by diluting appropriate volumes of the 100 mg/l K solutions to 100 ml in volumetric flasks using distilled water. Photometer readings of the standard solutions were recorded and a standard curve with K readings was constructed. Soil sample of 10 g was weighed into an extraction bottle. A 100 ml of 1.0 N NH_4OAc solution was added. The bottle and its contents were placed in mechanical shaker and shaken for 2 hours. The supernatant solution was filtered through No. 42 whatman filter paper. A 10 ml of aliquot was taken and read for K on a flame photometer after calibration of photometer with prepared standards. The photometer standard curve reading was used to determine the concentration of K in the soil.

Calculation

$$\text{Exchangeable K (mg/kg)} = \text{Graph reading (mg/kg)} \times 100 \times \text{Aliquot} \times \frac{\text{Dilution}}{\text{Weight of sample}} = \text{Graph reading x } 0.026 \qquad [6]$$

Determination of Calcium and Magnesium

A 10 g soil sample was weighed into an extraction bottle and 100 ml of 1.0 M ammonium acetate solution was added. The bottle with its contents was shaken for one hour. At the end of the shaking, the supernatant solution was filtered through No. 42

Whatman filter paper. A 10 ml portion of the extract was transferred to an erlenmeyer flask and 5 ml of ammonium chloride-ammonium hydroxide buffer solution was added followed by 1 ml of triethanolamine. Few drops of potassium cyanide and Eriochrome Black T solutions were then added. The mixture was titrated with 0.02N EDTA solution from red to blue end point.

Calculations:

$$Ca^{2+} + Mg^{2+} \text{ (or Ca) (cmol/kg soil)} = \frac{0.02 \times V \times 1000}{W} \quad [7]$$

Where:

W = weight in grams of soil extracted

V = ml of 0.02 N EDTA used in the titration

0.02 = concentration of EDTA used

3.6.2 Soil physical properties

The soil physical properties that were determined on the experiment fields are soil moisture content, bulk density, particle size distribution, soil texture and infiltration rate. Apart from soil moisture content which was taken only on-station, all other parameters were taken in all the experimental fields.

Soil Moisture

Soil moisture content was taken only on-station due to the availability of only one soil moisture probe. The aim of soil moisture measurements was to determine the effect of the various SWC measures on soil moisture content. Soil moisture was measured using an ML2 soil moisture probe supplied by Delta-T, Cambridge UK. The soil moisture probe is attached to a Delta-T Theta Meter, which contains an internal power supply. On activation, an electric current passes through four 15.24 cm long metals pined into the soil. The probe measures the moisture in the soil and the meter displays it in volumetric soil moisture content. Ten soil moisture measurements were made on each plot through the experiment at three days intervals.

Particle size distribution

The soil separates were determined by the hydrometer method. The method relies on the effects of settling differential velocities of sand, clay and silt particles within a water column. Once the sand, silt and clay distribution were measured, the soil may be assigned to a USDA texture class based on the soil textural triangle.

Fifty (50) grams of air-dried soil sample were weighed into a one–litre screw lid shaking bottle (W_T). Distilled water of 100 ml was added and the mixture was swirled to wet the soil thoroughly. Twenty millilitres of 30 % H_2O_2. H_2O_2 were added to destroy soil organic matter and free the individual soil particle sizes. Fifty millilitres of 5 % sodium hexametaphosphate solution were added. One drop of Amyl alcohol (95 %) was added and swirled gently to minimize foaming. It was shaken on a mechanical shaker for 2 hours and transferred into 1000 ml sedimentation cylinder. Distilled water was added to make up to the 1000 ml mark. The first hydrometer and temperature reading was recorded after 40 seconds. It was then allowed to stand for 3 hours for the second hydrometer and temperature reading to be recorded.

Calculation:

$$\%\ \text{Sand} = 100 - [\text{H1} + 0.2\ (\text{T1} - 20) - 2]\ \times 2 \qquad [8]$$

$$\%\ \text{Clay} = [\text{H2} + 0.2\ (\text{T2} - 20) - 2] \times 2 \qquad [9]$$

$$\%\ \text{Silt} = 100 - (\%\ \text{Sand}\ + \%\ \text{Clay}) \qquad [10]$$

Where:

WT = Total Weight of air-dried soil

H1 = 1st Hydrometer reading at 40 seconds

T1 = 1st Temperature reading at 40 seconds

H2 = 2nd Hydrometer reading at 3 hours

T2 = 2nd Temperature reading at 3 hours

Infiltration Rate

Before introduction of SWC measures, infiltration rates were measured by a bottom cut-out bucket (24 cm radius and 35 cm height) which served the same purpose as the single ring infiltrometer. First, the bottom of a plastic bucket was cut out and a ruler drawn on the inside. The top of the bucket is marked zero and indexed down to 35 cm. The bucket was put on top of the soil and pushed into the soil to about 10 cm so water does not leak out around the edge of the bucket. The bucket was then filled with water to the top and the stop watch started simultaneously.

The water level in the bucket was observed to ensure that the water does not leak out of the bucket. As the water level drops by 1 cm, the time was recorded; this was repeated until the water level had completely gone or until 30 minutes had passed

Once we had found the change in height and time, we then calculated the rate of infiltration (cm/h) by dividing the height of the water by the time

$$=> \frac{Height}{Time} = \frac{cm}{h} \quad [11]$$

All of the rates were then averaged to obtain the infiltration rate of the soil.

3.6.3 Crop growth measurements

At 50% tasseling and flowering stages, five plants were randomly chosen diagonally and tagged in each plot for the various physiological data to be taken. (Figure. 3.10). In all cases for the two, the right hand plant was chosen.

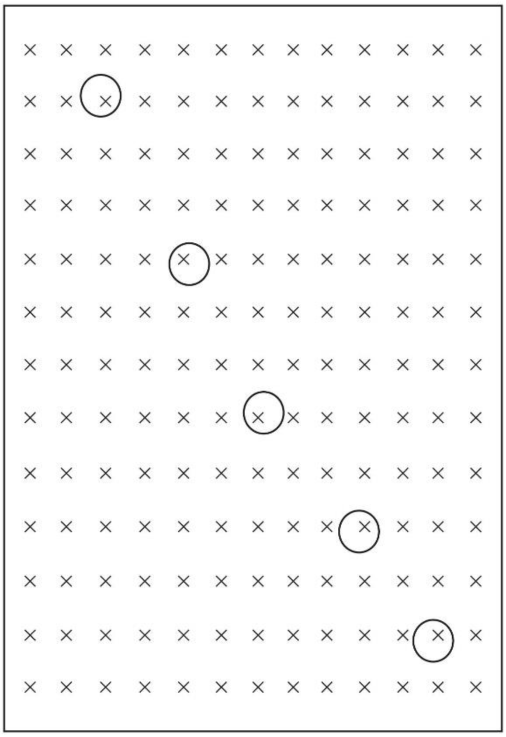


Fig. 3.10: Diagram showing sampling pattern

Plant height (cm)

Plant height was taken at flowering stage for the cowpea and at tasseling for the maize. A calibrated wooden rule was used to measure the plant height from the ground level to the last leaf and tassel for the cowpea and maize respectively.

Plant stem girth (cm)

The plant girth was measured using a string and a rule. The string was carefully wrapped around the stem at 5 cm from the ground for the cowpea and between second and third node for the maize. The point where the string made a complete circle to the stem was noted. The string was then removed and stretched on the ruler to get the length which corresponds to the stem girth.

Number of leaves per plant

The number of leaves of the plants were obtained by directly counting the functional leaves on the tagged plants.

Leaf area index (LAI)

The longest length and widest width of the leaf was first of all measured with the aid of a rule. Leaf area (LA) was determined by using Equation [12].

$$LA = L \times W \times r \qquad [12]$$

Where L = Leaf length

W = leaf width

r = Correction factor

r = 0.72 for cowpea as proposed by Hoyt and Brafield (1962)

r = 0.75 for maize as proposed by Kvet and Marshall (1971)

The leaf area index (LAI) was then computed by dividing the leaf area by the area the leaf occupied as shown in Equation [13].

$$LAI = \frac{LA}{A} \qquad [13]$$

Root biomass

Five plants on each plot outside the two middle rows were carefully removed with the help of a cylindrical ring while ensuring that all the roots were intact. The stems were then cut off leaving the roots only. The roots were oven dried at a temperature of 62^{o} C for 48 hours to ensure the moisture is taken out. The oven dried roots were then weighed.

Grain yield

Yields of the crops were taken per the two middle rows of the plot for each of the crops. The grains were then dried to about 12% moisture content and weighed. The weight which was obtained in Kg was converted into tonnes per hectare (t ha^{-1}) by the relationship in Equation [14].

$$\text{Yield}(t\ ha^{-1}) = \frac{\text{yield (kg)}}{3.75m^2} \times 10 \qquad [14]$$

Where $3.75m^2$ = area of the two rows

10 = conversion factor ($1kg/m^2$ = 10 t/ha)

3.6.4 Farmers' perceptions of erosion and SWC measures

A survey was carried out along with the experiment to identify the farmers' perception on soil erosion and SWC measures as a land management practice. In order to understand farmers' perception of SWC measures and factors affecting their SWC decision-making processes and related issues, formal interview using questionnaire was done. Also, informal interview was conducted with farm labourers and farmers who came in to observe the experiment.

It also sought to identify farmer's level of knowledge on erosion and SWC measures as land management practices and their knowledge on factors responsible for soil erosion. The formal interview was conducted with thirty (30) farmers from each region as respondents. Ten (10) farmers were selected randomly from each of the six study communities (Duko, Tingoli, Gbanjong, Bonia, Gia and Nyangua) for the interview. The informal interview sought to find out if farmers really perceive erosion as a serious problem and how they identify erosion on their farms or land. See Appendix 5 for sample questionnaire.

3.7 Statistical Data Analysis

Data obtained from this study were analysed with GENSTAT Statistical Package (GENSTAT, 9th Edition), Excel and Statistical Package for Social Sciences (SPSS). Analysis of Variance (ANOVA) was used to determine the variability in the various SWC measures effect on soil moisture content and on crop physiology and yield separately for the on-station and on-farm experiments. Least Significant Difference (LSD) at a significance level of 5% was used to compare and separate treatment means.

The data generated by the structured questionnaires were analyzed using SPSS. The data were thoroughly cleaned before the analysis by directly comparing all 60 cases with the original questionnaire. The relevant qualitative information generated by the informal discussions with farmers and other concerned bodies were integrated with the quantitative data for better understanding of the issues covered in the study.

CHAPTER FOUR

RESULTS

In this chapter, results for soil chemical and physical properties are presented. Also results for the effect of SWC measures on growth and yield components at the on-station and on-farms (Northern and Upper East Regions) are presented together with detailed statistical analyses. The results are presented for experiment 1 and experiment 2. Experiment 1 contains results obtained from the cowpea trial on both the on-station and on-farm whilst experiment 2 contains results from the maize trial for both on-station and on-farm.

4.1 Soil Physiochemical Properties

This refers to the chemical and physical properties of the soil that were determined from the experimental field using sample soils collected prior to the experiment.

4.1.2 Chemical properties

The chemical properties of the soil samples collected at the beginning of the experiment in the on-station and on-farm are presented in Table 4.1. Data on organic carbon, organic matter, total nitrogen, exchangeable cations (K, Na, Ca and Mg) and pH were determined.

Table 4.1: Physiochemical properties of soils in the communities of study

Properties		Communities						
		Northern Region				Upper East Region		
		Tamale Airport	Duko	Tingoli	Gbanjong	Bonia	Gia	Nyangua
%	Organic carbon	0.84	0.81	0.59	0.53	0.66	0.63	0.75
	Organic matter	1.44	1.4	1.02	0.91	1.14	1.09	1.29
	Total N (%)	0.13	0.11	0.12	0.13	0.03	0.04	0.03
Exchangeable cations (mg/kg)	K	0.15	0.19	0.08	0.08	0.14	0.16	0.19
	Na	0.21	0.13	0.04	0.04	0.13	0.09	0.13
	Ca	5.48	3.2	2.94	2.14	1.87	1.87	1.74
	Mg	0.88	0.53	1.07	0.27	0.8	0.53	0.4
	pH	4	6.37	5.99	6.62	5.84	6.12	5.91
Particle size (%)	Sand	54.31	50.24	68.56	57.38	77.36	81.72	78.14
	Silt	24.73	39.36	11	34.62	14.64	12.24	15.86
	Clay	12.82	10.4	20.44	8	8	6	6
	Texture	Sandy Clay L.	Loam	sandy loam	Sandy loam	sandy loam	loamy sand	loamy sand
Infiltration rate	(cm h^{-1})	7.6	7.38	5.68	5.62	6.38	7.60	8.26

4.1.1 Physical properties

Data on soil moisture content was collected only from the on-station trial and is presented in detail in both experiment one and two for the cowpea and maize cultivations respectively (See sections 4.2.1 and 4.3.1). Information on infiltration rates and particle size distribution are available for both the on-station and on-farm trials Table 4.1 presents information on the infiltration rates and particle size distribution

4.2 Experiment One Results

The results in experiment one are the effect of the SWC measures on cowpea cultivation at the on-station and on-farm (Northern and Upper East Region) trials.

4.2.1 Effect of soil and water conservation measures on soil moisture for cowpea cultivation

Data on soil moisture was taken on-station only. The data were analysed using one way ANOVA with the four replicates and four treatments as independent factors. On each plot, 10 soil moisture measurements were made two weeks after planting, over the season at three days intervals at 8.00h GMT on each occasion. Significant effects ($P < 0.05$) were found in all the 10 cases among the conservation practices (Figure 4.1). The significant differences were noticed between the SWC measures, [contour ridges (CR), half-moon (HM), contour farming (CF)] and farmers' practice (FP) as the control. In some few cases, there were significant difference among the SWC measures i.e. CR, HM and CF. In six out of the ten cases, CF gave the highest moisture content compared to the treatments.

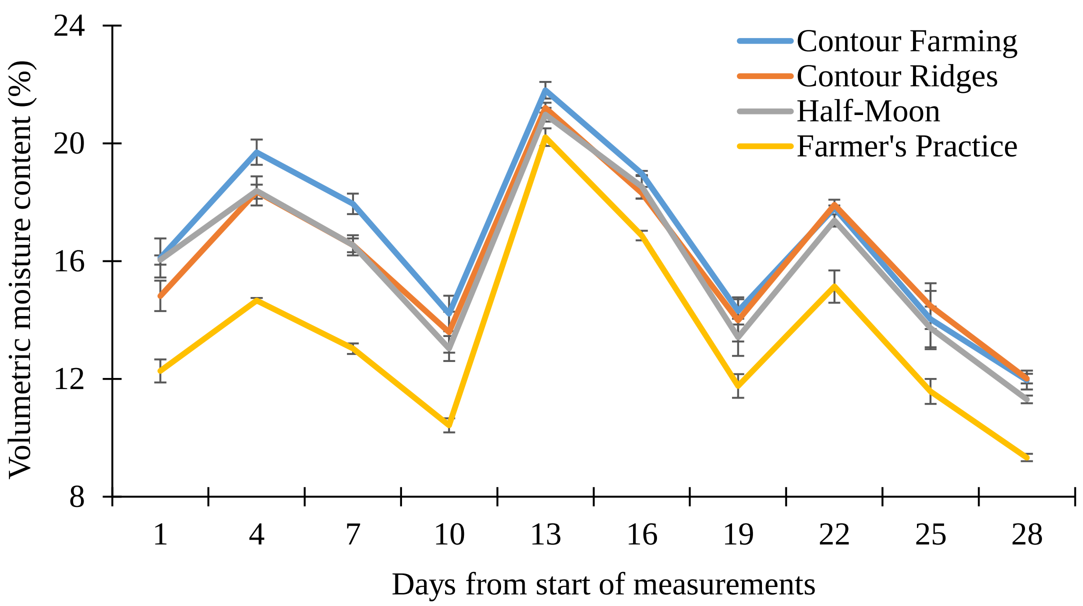


Fig. 4.1: Effect of soil and water conservation measures on soil moisture for cowpea trial

4.2.2 Effect of soil and water conservation measures on cowpea height at flowering

The effect of the SWC measures on *Songotra* cowpea height at flowering at the on-station and on-farm (Northern and Upper East Region) are presented in Table 4.2. Analysis of variance showed no significant difference in *Songotra* cowpea height between the different SWC measures in on-station and on-farm (Northern and Upper East Region) trials.

Table 4.2: Effect of soil and water conservation measures on cowpea height in on-station and on-farm trials

	Mean stem girth (cm)		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	30.8	31.6	26.5
Contour ridges	30.3	32.7	24.5
Half-moon	34.9	31.5	26.1
Farmers practice	29.9	29.1	27.8
P-value	0.1	0.4	0.2

4.2.3 Effect of soil and water conservation measures on cowpea stem girth at flowering

Stem girth is an important component of plant growth. Table 4.3 illustrates the mean values of stem girth of *Songotra* cowpea at 50% flowering at the on-station and on-farm (Northern and Upper East Regions) trials. Stem girth was significantly affected by the SWC measures at 50% flowering stage of the plant in on-station and the Northern Region. In the Upper East Region however, stem girth was not significantly affected by the SWC measures.

Table 4.3: Effect of soil and water conservation measures on cowpea stem girth in on-station and on-farm trials

	Mean stem girth (cm)		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	2.3 b	3.3 a	2.7
Contour ridges	2.8 a	3.0 b	2.8
Half-moon	2.5 b	3.0 b	2.7
Farmers practice	2.3 b	3.2 b	2.7
P-value	0.0	0.0	0.3

4.2.4 Effect of soil and water conservation measures on cowpea number of leaves at flowering

Table 4.4 shows the effect of SWC measures on *Songotra* cowpea number of leaves per plant at 50% flowering stage at the on-station and on-farm (Northern and Upper East Regions) trials. Though the SWC treatments had more leaves at 50% flowering, there was no significant effect ($p > 0.05$) of the SWC practices on the *Songotra* cowpea number of leaves per plant in all the trials (i.e. in on-station and on-farm trials).

Table 4.4: Effect of soil and water conservation measures on cowpea number of leaves in on-station and on-farm trials

	Mean number of leaves		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	56.9	59.5	63.8
Contour ridges	59.5	61.3	66.2
Half-moon	50.6	67.3	63.9
Farmers practice	52.2	61.9	63.3
P-value	0.2	0.1	0.3

4.2.5 Effect of soil and water conservation measures on cowpea leaf area index at flowering

There was no significant effect (P > 0.05) of the SWC measures on LAI at the on-station trial. However, leaf area index (LAI) was significantly affected (P < 0.05) by the treatments at 50% flowering of the *Songotra* cowpea in the on-farm (Northern and Upper East Region) trials. All the SWC measures treatments (CR, CF and HM) recorded significant values over the control treatment (FP). Table 4.5 shows SWC measures means on cowpea LAI.

Table 4.5: Effect of soil and water conservation measures on cowpea LAI in on-station and on-farm trials

	Mean LAI		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	0.7	0.8 a	0.8 a
Contour ridges	0.7	0.7 a	0.8 a
Half-moon	0.7	0.8 a	0.7 a
Farmers practice	0.6	0.6 b	0.6 b
P-value	0.1	0.0	0.0

4.2.6 Effect of soil and water conservation measures on cowpea root biomass at flowering

Table 4.6 presents the mean values of the *Songotra* cowpea root biomass at 50% flowering at the on-station and on-farm trials (Northern and Upper East Regions). One way ANOVA showed no significant difference (P > 0.05) between the SWC measures treatments for cowpea root biomass in the on-station and Upper East trials. There was however a significant effect (P < 0.05) between the SWC measures (CR, HM and CF) and the control (FP) on root biomass in the Northern Region.

Table 4.6: Effect of soil and water conservation measures on cowpea root biomass in on-station and on-farm trials

	Mean root biomass (g)		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	20.5	19.9 a	12.9
Contour ridges	19.0	18.2 a	13.9
Half-moon	17.9	19.0 a	15.1
Farmers practice	15.3	16.7 b	14.4
P-value	0.1	0.05	0.4

4.2.7 Effect of soil and water conservation measures on cowpea grain yield

The influence of the different SWC practices on the *Songotra* cowpea grain yield at the on-station and on-farm (Northern and Upper East Regions) trials is shown in Table 4.7. Cowpea grain yield was significantly affected ($P < 0.05$) by the SWC measures (CF, HM and CR) in the Northern Region. Both the on-station and Upper East trials showed no significant effect ($P > 0.05$) of the SWC measures on grain yield.

Table 4.7: Effect of soil and water conservation measures on cowpea grain yield in on-station and on-farm trials

	Mean grain yield (t ha^{-1})		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	1.8	1.8 a	1.6
Contour ridges	1.8	1.5 b	1.5
Half-moon	1.7	1.8 a	1.5
Farmers practice	1.4	1.5 b	1.5
P-value	0.1	0.0	1.0

4.3 Experiment Two Results

This section presents the results obtained for growth and yield components of maize as affected by the SWC measures at the on-station and on-farm (Northern and Upper East Region) trials.

4.3.1 Effect of soil and water conservation measures on soil moisture for maize cultivation

Like the cowpea trial, data of moisture content on the maize trial were analysed using one way ANOVA with four treatments as independent factors. On each plot, ten (10) soil moisture measurements were made two weeks after planting, over the experiment period at three days intervals at 8.00h GMT on each occasion. Significant effect ($P < 0.05$) was found in all the 10 cases of the maize trial as similar to the cowpea trial. In nine out of the ten (10) cases, CF had the highest soil moisture content. In some of the cases there were significant difference among the SWC measures (CR, CF and HM) Figure 4.2 presents the effect of the SWC measures on moisture for the maize trial.

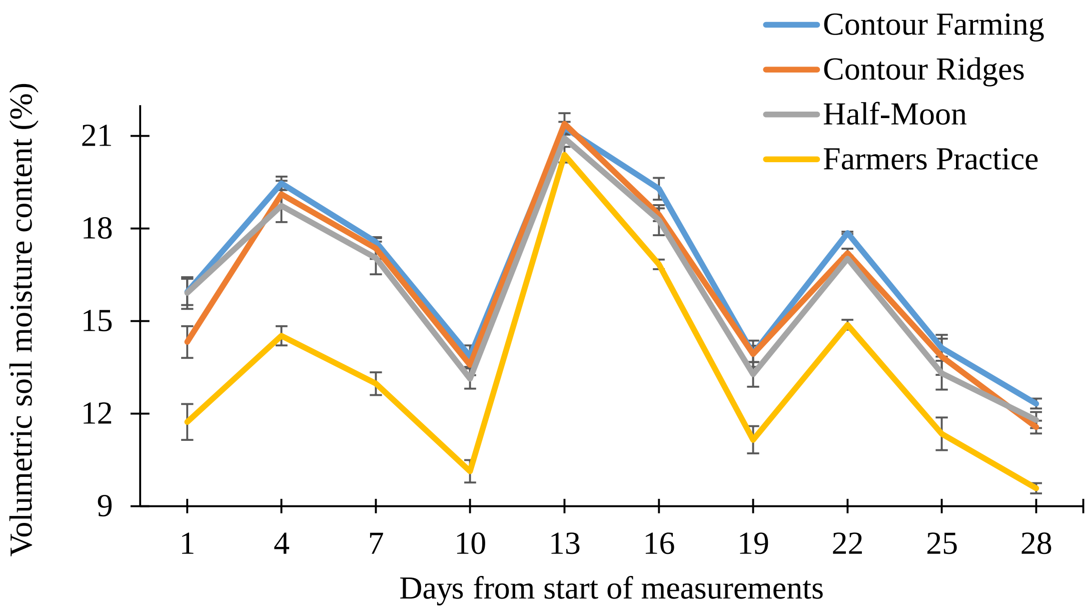


Fig. 4.2: Effect of soil and water conservation measures on soil moisture for maize trial

4.3.2 Effect of soil and water conservation measures on maize height at tasseling

The effect of SWC measures on the *Omankwa* maize height at 50% tasseling is presented in Table 4.8. Analysis of variance of maize height data taken at 50% tasseling showed significantly taller *Omankwa* maize plants for the different SWC practices (CF, HM and CR) compared to the control (FP) in the on-station and Upper East trials. No significant effect of SWC measures on maize height was however observed in the Northern Region.

Table 4.8: Effect of soil and water conservation measures on maize height in on-station and on-farm trials

	Mean height (cm)		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	101.0 a	134.7	102.7 a
Contour ridges	101.8 a	146.3	100.0 a
Half-moon	91.4 a	138.3	98.9 a
Farmers practice	76.5 b	117.3	91.1 b
P-value	0.0	0.1	0.0

4.3.3 Effect of soil and water conservation measures on maize stem girth at tasseling

The effect of the SWC measures treatment on *Omankwa* maize stem girth at 50% tasseling was significant at ($p < 0.05$) at the on-station trial. No significant treatments effect ($P > 0.05$) was observed in the on-farm (Northern and Upper East Region) trials. Table 4.9 shows SWC measures effect on maize stem girth in the on-station and on-farm trials.

Table 4.9: Effect of soil and water conservation measures on maize stem girth in on-station and on-farm trials

	Mean stem girth (cm)		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	6.0 a	7.1	6.6
Contour ridges	5.7 a	7.1	6.7
Half-moon	5.3 b	6.6	6.5
Farmers practice	4.8 b	6.4	5.8
P-value	0.0	0.5	0.1

4.3.4 Effect of soil and water conservation measures on maize number of leaves at tasseling

Table 4.10 presents the mean number of leaves for the *Omankwa* maize plant in the on-station and on-farm trials (Northern and Upper East Regions). At 50% tasseling of the maize plant, no significant treatment effect (P > 0.05) was observed between the treatments on number of leaves for the on-station and on-farm (Northern and Upper East Region) trials.

Table 4.10: Effect of soil and water conservation measures on maize number of leaves in on-station and on-farm trials

	Mean number of leaves		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	10.2	10.4	10.3
Contour ridges	9.9	10.5	10.0
Half-moon	10.1	10.4	9.9
Farmers practice	9.9	10.4	9.9
P-value	0.4	0.9	0.5

4.3.5 Effect of soil and water conservation measures on maize leaf area index (LAI) at tasseling

The effects of the different SWC practices on LAI of the *Omankwa* maize plant is presented in Table 4.11. No significant effect (P > 0.05) of treatments on LAI was observed in the on-station and Northern Region trials. However, SWC practices on LAI at 50% tasseling had a significant effect (P < 0.05) in the Upper East Region trial.

Table 4.11: Effect of soil and water conservation measures on maize LAI in on-station and on-farm trials

	Means LAI		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	5.2	5.5	5.2 a
Contour ridges	5.2	5.5	5.0 a
Half-moon	5.0	5.5	5.0 a
Farmers practice	5.0	5.3	3.8 b
P-value	0.4	0.9	0.0

4.3.6 Effect of soil and water conservation measures on maize root biomass at tasseling

Influence of the SWC practices on root biomass of the *Omankwa* maize plant is presented in Table 4.12. Analysis of variance after 50% of maize tassel, showed significant difference ($P < 0.05$) between the treatments in the on-station trial. No significant effect ($P > 0.05$) was however observed between treatments on root biomass in the on-farm trials (Northern and Upper East Regions).

Table 4.12: Effect of soil and water conservation measures on maize root biomass in on-station and on-farm trials

	Mean root biomass (g)		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	30.8 a	30.6	25.4
Contour ridges	28.4 a	27.6	23.8
Half-moon	28.7 a	26.4	22.8
Farmers practice	21.9 b	24.7	25.2
P-value	0.0	0.3	0.8

4.3.7 Effect of soil and water conservation measures on maize grain yield

Grain yield of the *Omankwa* maize was taken from sample plants after maturity. The grain yield in t ha^{-1} at 12% moisture content was calculated per plot and one way analysis of variance carried out. Significant difference was observed between the treatments on grain yield in all the experimental areas (i.e. on-station, Northern Region and Upper East Region trials). Table 4.13 shows SWC measures effect on *Omankwa* maize grain yield.

Table 4.13: Effect of soil and water conservation measures on maize grain yield in on-station and on-farm trials

	Mean grain yield (t ha^{-1})		
SWC measures	On-station	Northern Region	Upper East Region
Contour farming	2.2 a	5.8 a	5.1 a
Contour ridges	1.9 a	5.8 a	4.2 b
Half-moon	1.9 a	5.5 a	3.9 b
Farmers practice	1.1 b	3.7 b	2.5 c
P-value	0.0	0.0	0.0

4.4 Farmers' Perception of Soil Erosion and SWC Measures

One of the objectives of this study was to find out farmers' knowledge about SWC measures, soil erosion and its causes with thirty (30) respondents in each region. The key indicators from the results of the survey revealed that farmers' knowledge of soil erosion and its causes include: cultivation along steep slope, poor SWC measure, excessive rainfall, continuous cropping, over grazing and deforestation. Table 4.14 shows the percentage of respondents that had awareness of soil erosion and Table 4.15 shows the percentage of the respondents who had knowledge of SWC measures as erosion control techniques. Table 4.16 presents the number of respondents who perceived the various factors as causes of soil erosion.

Table 4.14: Farmers' awareness level of soil erosion in Northern and Upper East Regions of Ghana, 2014

Awareness level	Awareness level (%)	
	Northern Region	Upper East Region
Nil	0.0	0.0
Poor	40.0	43.3
Good	36.7	40.0
Very good	23.3	16.7
Total	**100.0**	**100.0**

Table 4.15: Farmers' knowledge level of Soil and water conservation measures in Northern and Upper East Regions of Ghana, 2014

Knowledge level	Location / Region	
	Northern Region	Upper East Region
Nil	10.0	20.0
Poor	46.7	53.3
Good	40.0	20.0
Very good	3.3	6.7
Total	**100.0**	**100.0**

Table 4.16: Farmers' response to causes of soil erosion in Northern and Upper East Regions of Ghana, 2014

	Frequency of response			
Main causes	Northern Region	Rank	Upper East Region	Rank
Cultivation along steep slopes	29	1st	28	1st
Poor SWC practices	21	3rd	18	4th
Excessive rainfall	25	2nd	22	2nd
Population pressure	13	6th	19	3rd
Continuous cropping	21	3rd	14	6th
Deforestation	19	5th	17	5th
Over grazing	9	7th	11	7th

CHAPTER FIVE

DISCUSSION

In this chapter, results of analysed data are discussed. These are discussed with reference to the aims and objectives of the study. Firstly, the effect of the soil and water conservation (SWC) measures on soil moisture content is discussed. This is followed by a discussion of the effect of the soil and water conservation measures (treatments) on growth and yield components of cowpea and maize at the on-station and on-farm (Northern and Upper East Region) trials. Discussions are presented for experiment 1 and experiment 2 for the cowpea and maize trials respectively.

5.1 Discussion on effect of soil and water conservation measures on cowpea trial (Experiment 1)

In this section, discussion of the results obtained from the cowpea trial in both the on-station and on-farm trials (Northern and Upper East Regions) is presented.

5.1.1 Effect of soil and water conservation measures on soil moisture for cowpea cultivation

Soil and water conservation (SWC) measures significantly reduce rain water loss through runoff compared to the farmers practice (Gebreegziabher *et al.,* 2009). In the cowpea trial, the CF retained the highest soil moisture on average for the first three weeks (first seven set of data recorded). The CR on average, produced the highest soil moisture in the fourth week (last three set of data gathered). Thus the CF-Cowpea combination retained more moisture initially but was overtaken by CR-Cowpea in the later stages of the experiment.

For higher soil moisture condition purposes, one may opt for CF or CR depending on when it is critical (i.e. early or later stage of the cowpea crop). The FP which is the control treatment recorded the least soil moisture throughout the experiment. On the average over the first four weeks, there was about 23.40% increase in soil moisture in the CF treatment compared to the FP. In the other treatments, CR had about 19.2% whilst HM had about 17.8% increase in moisture compared to the FP. This result is similar to Sastry (2002) who reported that the in-situ rainwater conservation such as compartmental bunding, contour farming and broad bed furrow system conserve the rain water in-situ and also reduce soil erosion. Kiran and Lingaraju (2004) also reported similarly that, among the in-situ moisture conservation practices, ridges and furrows and compartmental bunding were found beneficial in conserving higher soil moisture as compared to flat bed.

The outstanding performance of CF over the other conservation measures (HM, CR and FP) is probably due to the fact that CF has many series of ridges and furrows which are very close to each other, all of which act as reservoirs to catch and retain rainwater, thus permitting increased infiltration and more uniform distribution of the water. CR and HM on the other hand have ridges and semi-circular bunds that have comparatively wider spaces in between. These wider spaces between ridges allow some run-off and reduces the infiltration and uniform distribution of the rain water.

5.1.2 Effect of soil and water conservation measures on cowpea height

In terms of cowpea height, only at the on-station trial that the treatments had significant effect at $P < 0.05$. The on-station trial had the SWC measures (HM, CR and CF) performing better than the control (FP). The HM recorded the highest height of 34.9

cm which is about 16.7% taller than the FP whilst the CF (30.6 cm) and CR (30.3 cm) were about 2.8% and about 1.4% taller than the FP (29.9 cm) respectively This result is similar to Ramesh and Rathika (2009) who reported higher plant heights in compartmental bunding, ridges, furrows and tide ridging compared to the farmers practice. .

Though there was no significant treatments effect on cowpea height in the Northern Region, the SWC measures (HM, CR and CF) performed better than the control (FP). Effect of the SWC practices on cowpea height was in the order CR (32.7 cm) > CF (31.6 cm) > HM (31.5 cm) > FP (29.1 cm). The CR was about 12.4% taller than the FP whilst the CF and HM were about 8.5% and 8.2% taller than the FP respectively. Increasing soil moisture created by the conservation measures probably created an ideal condition which influenced the growth of the crop resulting in higher plant heights for the SWC measures.

Effect of the SWC practices on cowpea height in the Upper East Region was also not significantly different, with the control (FP) recording the tallest plants over the SWC measures (HM, CR and CF). The CR recorded the least height of 24.5 cm which is about 11.8% shorter than the FP. The HM and CF had heights of 26.1 cm and 26.5 cm which were about 6.2% and 4.8% respectively shorter than the FP which recorded the tallest height of 27.8 cm.

Comparatively, the Northern Region recorded higher mean values of height than the Upper East Region. For the Upper East trial, cowpea height was 26.2 cm on average and in the Northern Region it was 31.3 cm on average which is about 19.2% more than the height of Upper East Region. This result may be due to other factors such as rainfall and soil nutrient variations in the two regions.

5.1.3 Effect of soil and water conservation measures on cowpea stem girth

There was significant treatment effect on stem girth in the on-station cowpea trial. The SWC measures performed significantly better than the FP with the CR recording the biggest stem girth. The CR (2.8 cm) was about 23.4% bigger than FP, which had a girth of 2.3 cm. The HM (2.5 cm) and CF (2.3 cm) were about 9.6% and 3.3% bigger than the FP respectively. The performance of the SWC measures (CF, HM and CR) over the FP in the on-station trial in terms of stem girth may be associated with increased soil moisture content in the SWC measures.

Significant treatment effect on cowpea stem girth was also observed in the Northern Region. The CF had the biggest stem girth of 3.3 cm which is about 4.8% bigger than the FP (3.2 cm). The HM and the CR had girths of 2.98 cm and 2.97 cm which are about 5.7% and 6.0% less compared to the control (FP) respectively. Other factors may have caused the HM and CR to perform less than the FP in the Northern Region considering the trend of the results.

In the Upper East Region, there was no significant difference ($P > 0.05$) between treatments (CF, HM and CR) and the control (FP) for stem girth. SWC measures however had bigger stem girths than the control (FP). CR and CF had stem girths of 2.8 cm and 2.7 cm which were about 7.0% and 1.5% bigger than the FP respectively. The HM had a stem girth of 2.653 cm compared to FP stem girth of 2.647 cm.

The Northern Region had higher mean values of stem girth than the Upper East Region. Averagely, the Upper East Region had a stem girth of 2.7 cm and the Northern Region had 3.1 cm which is about 14.8% bigger than that of the Upper East. Favourable climatic and soil conditions in the Northern Region may be responsible for the region's better performance over the Upper East Region.

5.1.4 Effect of soil and water conservation measures on cowpea number of leaves

There was no significant effect of the SWC measures on the cowpea leaves at 50% flowering in the on-station trial. The CR and CF with mean leaf numbers of 59.5 and 56.9 respectively, performed better than the FP with a mean leaf number of 52.2. The HM had the least number of leaves of 50.6. The CR and the CF were about 14.0% and 9.0% more than the FP respectively, with the HM being about 3.1% less compared to the FP.

There was no significant difference among treatments for cowpea number of leaves in the Northern Region as well. The HM had the highest number of leaves of 67.3 (about 8.6% more than the FP) followed by the FP with 61.9 leaves. The CR and CF had 61.3 and 59.9 leaves which are about 1.1% and 3.9% less compared to the FP respectively.

In the Upper East Region, there was no significant effect among treatments on number of leaves. The SWC measures however had more leaves than the control. The CR had the highest number of leaves of 66.2 which is about 4.5% more than the FP. The HM and CF had 63.9 and 63.8 leaves which are about 0.9% and 0.7% more than the FP respectively. The SWC measures higher number of leaves over the control could be due to the ability of the SWC measures to retain more moisture compared to the FP.

Comparatively, the Upper East Region recorded higher mean values than the Northern Region in terms of leaf number. This result could be due to other conditions in the Upper East Region that favoured the cowpea. On the average, the Upper East Region had 64.3 leaves and the Northern Region had 62.5 which is about 2.9% less than the Upper East Region.

Though there were no significant difference on number of leaves, in the trials, the better performance of the SWC measures over the control could be one of the key factors that are responsible for the higher performance in the growth and yield components of the plants in the SWC measures. This result is supported by Maddonni *et al.* (2006) who reported that, crop growth depends on the amount of intercepted photosynthetic active radiation and the efficiency to convert the intercepted photosynthetic active radiation into aboveground phytomass, commonly referred to as radiation use efficiency.

5.1.5 Effect of soil and water conservation measures on cowpea leaf area index (LAI)

At the on-station, there was no significant difference ($P > 0.05$) between the treatments (CR, CF and HM) and the control (FP) for LAI. Higher means of LAI were however observed in the SWC measures. The CF and HM respectively recorded 0.729 and 0.728 which are about 23.8% and 23.6% higher than the FP which had a LAI of 0.6. The CR had 0.7 LAI which is about 11.2% more compared to the FP.

Significant treatment effect was observed for LAI between the treatments in the Northern Region. The SWC measures performed better than the control. The HM (0.8), CF (0.8) and CR (0.7) had about 38.3%, 35.8% and 18.7% increase in LAI respectively over the FP. This result could be due to the ability of SWC measures to conserve more soil moisture than the control. The Upper East Region also had significant difference ($P < 0.05$) between the treatments on LAI. The SWC measures all recorded higher LAI compared to the control (FP). The CR had the highest LAI of 0.8 which is about 29.6% more than the FP of 0.6 LAI. The CF and HM had 0.8 and 0.7 LAI which are about 27.6% and 9.7% more than the LAI of the FP respectively.

Higher LAI was observed in the Upper East Region compared to the Northern Region. On the average, Upper East had LAI of 0.7 and the Northern Region had 0.7 which is about 0.8% less. The significant effect of the SWC measures on the LAI could also be one of the factors for the high performance of the SWC measures on growth and yield components of the cowpea because the larger the LAI the greater the photosynthetic effect.

5.1.6 Effect of soil and water conservation measures on cowpea root biomass

There were significant difference among treatments of the cowpea root biomass at the on-station trial. The SWC measures performed better than the control treatment with the CF recording the largest root biomass of 20.5 g which is 34.4% larger than the FP which had a root biomass of 15.3 g. The CR and HM had 19.0 g and 17.9 g which are about 24.6% and 17.5% larger than the FP respectively. The performance of the SWC measures over the control could be ascribed to the higher moisture content in the SWC measures.

The SWC measures in the Northern Region also had significant effect at $P < 0.05$ on the root biomass of the cowpea plant. The CF recorded a root biomass of 19.9 g which is 20.1% larger than that of the FP as control. The HM and the CR had root biomasses of 19.0 g and 18.2 g which are 14.7% and 10.0% larger than the FP which had a root biomass of 16.6 g. The high moisture content in the SWC measures could be responsible for the higher root biomasses observed for the SWC measures.

There was no significant effect of the treatments on root biomass was in the Upper East Region. The HM had the largest root biomass of 15.1 g being about 4.6% larger than the FP of 14.4 g of root biomass. The CR and CF had 13.9 g and 12.9 g of root biomasses which are about 3.8% and 10.7% smaller compared to the FP respectively. The FP in the Upper Region had a higher root biomass than the CR and CF.

The overall performance in the Northern Region in terms of root biomass was better than the Upper East Region considering the mean values. The Upper East Region on average had root biomass of 14.1 g and Northern Region had an average root biomass of 18.4 g which is about 30.8% higher. This result may be due to other factors such as rainfall and soil nutrient variations in the two regions.

The performance of the SWC measures (CF, HM and CR) over the FP treatment in terms of root biomass may be associated with increased soil moisture content in the SWC measures. The performance of the SWC measures on root biomass over the control could also be a factor for the high performance of the SWC measures on growth and yield components of the cowpea plant.

5.1.7 Effect of soil and water conservation measures on cowpea grain yield

There was no significant effect among SWC measures (CF, HM and CR) and farmer practice (FP) of cowpea grain yield for the on-station trial. However, the SWC measures higher mean values compared to the FP with the CF yielding 1.8 t ha^{-1} of cowpea which is about 29.7% more than the FP which yielded 1.5 t ha^{-1}. The CR yielded 1.8 t ha^{-1} of cowpea which is about 23.8% more than the FP whilst the HM yielded 1.7 t ha^{-1} being about 20.8% more than the FP.

Grain yield was significantly affected by the SWC measure treatments for the Northern Region trial. The highest yield was observed under the CF with 1.8 t ha^{-1} (about 24.5% more than the FP). Grain yield of 1.8 t ha^{-1} and 1.5 t ha^{-1} being about 22.8% and 2.0% more than the FP (1.5 t ha^{-1}) respectively, were obtained for the HM and CR. The performance of CF above the other conservation practices is probably due to the fact that it retained more moisture compared to the other SWC practices. The increase in cowpea grain yield under the SWC measures may have resulted from better soil moisture retention that was provided by the SWC measures.

There was no significant treatments effect on cowpea grain yield for the Upper East Region. The CF yielded the highest grain yield of 1.8 t ha^{-1} which is about 3.1% more than the FP which recorded 1.5 t ha^{-1} of yield. The HM recorded a yield of 1.5 t ha^{-1} (about 1.1% more than the FP) whilst the CR recorded the lowest yield of 1.5 t ha^{-1} which is about 1.3% less than the FP.

Yield in the Northern Region was higher than yield in the Upper East Region. On the average, Upper East Region yielded 1.5 t ha^{-1} whilst the Northern Region yielded 1.6 t ha^{-1} which is about 6.5% higher. Difference in yield between the regions may be due to factors such as rainfall and soil nutrient variations in the two regions. To improve the yield of cowpea, one may opt for any of the SWC measures depending on which one will be more convenient to apply.

5.2 Discussion of effect of soil and water conservation measures on maize trial (Experiment 2)

In this section, discussion of the results obtained from the maize trial in both the on-station and on-farm trials (Northern and Upper East Regions) is presented.

5.2.1 Effect of soil and water conservation measures on soil moisture for maize cultivation

Similar to the cowpea trial, SWC measures had significant effect on soil moisture content with the CF giving the highest soil moisture on average, followed by the CR with the second highest soil moisture content. The FP which is the control had the least soil moisture throughout the four weeks of measurements. The CF on average, had about 24.0% increase in moisture over the FP with CR and HM having about 20.4% and 19.4% increase in moisture over the FP respectively.

The ability of the SWC measures to retain more soil moisture than the control may be the reason behind the SWC measures better performance over the control in terms of growth and yield components of the maize plant. This is supported by Gebreegziabher *et al*. (2009) who reported that SWC measures significantly reduced rain water loss through runoff compared to the farmers practice. Similarly, Chittaranjan and patnaik (1981) also observed increased soil moisture conservation due to contour bunding, broad based terrace and zing conservation terrace. The significant reduction of runoff with resulting increase in soil moisture under the SWC measures may be ascribed to the combined effect of arrangement of crops across the slope, furrows and bed structures.

5.2.2 Effect of soil and water conservation measures on maize height at tasseling

Significant difference in maize height was observed between the SWC treatments (i.e. CF, CR and HM) and the control (FP) in the on-station trial. The CR had a height of 101.8 cm which is about 33.1% taller than the FP which had a height of 76.5 cm. The CF and HM had heights of 101.0 cm and 91.4 cm which are about 32.0% and 19.5% taller than the FP respectively. Similarly, Munish *et al.* (2008) observed the tallest sorghum heights on ridges and furrows with the lowest heights observed on flat bed.

No significant treatment effect on maize height was observed in the Northern Region trial. SWC measures however gave higher maize heights than the control. The CR which was about 24.7% taller than the FP, had a height of 146.3 cm. The HM and CF were about 17.9% and 14.83% taller than the FP with heights of 138.3 cm and 134.7 cm respectively. The FP had the least height of 117.3 cm.

There was significant difference of maize height in the Upper East Region. The CF had the highest height of 102.7 cm which is about 12.8% higher compared to the FP which had a height of 91.1 cm. The CR and HM were about 9.8% and 8.6% higher with heights of 100.0 cm and 98.9 cm compared to the FP respectively. Similarly, Ramesh and

Rathika (2009) observed that, conservation of rain water through land configuration techniques such as compartmental bunding, ridges and tide ridging have considerably improved plant growth parameters like plant height. Increasing soil moisture content created by the conservation measures probably created an ideal condition which influenced the growth of the crop resulting in higher maize heights in the SWC measures.

The Northern Region had higher mean heights compared to Upper East Region. On average, Upper East had a maize height of 98.2 cm and the Northern Region had an average height of 134.2 cm which is about 36.7% higher. This difference may be attributed to variations in factors such as soil and climate conditions in the regions.

5.2.3 Effect of soil and water conservation measures on maize stem girth at tasseling

There was significant differences in stem girth among the treatments for the on-station trial. The CF produced the biggest stem girth of 6.0 cm (about 24.8% bigger than the FP). The CR had the second biggest stem girth of 5.7 cm (about 18.3% bigger compared to FP). The HM had a girth of 5.3 cm which is about 12.0% bigger than the FP which had the least stem girth of 4.8 cm.

The trial in Northern Region showed no significant treatment effect on stem girth. The SWC measures however had bigger stem girths compared to the FP. The CR (7.1 cm) was about 11.5% bigger than the FP (6.4 cm). The CF (7.1 cm) and the HM (6.6 cm) were about 11.0% and 3.5% bigger than the FP respectively. The Upper East Region trial too had no significant treatment effect on stem girth. The SWC measures however recorded bigger stem girths than the FP which had the least stem girth of 5.8 cm. The CR (6.7 cm) was 14.4% bigger than the FP whilst the CF (6.6 cm) and HM (6.5 cm) were about 12.4% and 11.7% bigger in stem girth compared to the FP respectively. The mean stem girth in the Northern Region was bigger than the Upper East Region. The Upper East Region had an average stem girth of 6.4 cm and the Northern Region had an average stem girth of 6.8 cm which is about 6.1% bigger. Variation in climatic and soil conditions may be responsible for the better performance of the Northern Region over the Upper East Region.

5.2.4 Effect of soil and water conservation measures on maize number of leaves at tasseling

The SWC measures at the on-station trial had significant effect on number of maize leaves. The SWC measures performed better than the control (except for the CR). The CF gave the highest number of leaves of 10.2 with about 3.3% increase over the FP. The HM had 10.1 leaves which is about 2.3% more whilst the CR had 9.9 leaves, being about 0.3% less compared to the FP which had 9.9 leaves. A similar result was reported by Taley *et al*. (2014) who observed that, ridges and furrow methods of moisture conservation showed significantly higher number of functional leaves per plant in comparison to other practices.

The effect of the SWC measures on maize leaves was insignificant in the Northern Region trial. All the SWC measures performed better than the FP except for the HM. The CR had 10.5 leaves being about 1.3% more compared to the FP which had 10.4 leaves. The CF had 10.4 leaves being about 0.3% more than the FP whilst the HM had 10.4 leaves which is about 0.3% less compared to the FP. In Upper East Region, there was also no significant effect of treatments on the maize number of leaves. The SWC measures however had more leaves than the control. The CF had 10.2 leaves being about 3.7% more than the FP. The CR and the HM respectively had 10.0 and 9.9 leaves which were about 1.3% and 0.3% more compared to the FP which had 9.9 leaves.

Increasing soil moisture content created by the conservation measures probably created an ideal condition which influenced the growth of the crop resulting in higher number of leaves in the SWC measures compared to the control. The higher number of leaves in the SWC measures over the control could be a factor for the high performance of the SWC measures on growth and yield components of the maize plant. Higher mean number of leaves were observed in the Northern Region compared to the Upper East Region. Comparatively, the Northern Region had 10.4 leaves on average whilst the Upper East Region had an average leaf number of 10.0 which is about 4.0% less to the Northern Region. This could as well be due to variation in terms of climatic and soil conditions in the two regions.

5.2.5 Effect of soil and water conservation measures on maize leaf area index (LAI) at tasseling

There was no significant effect of treatments on maize LAI for the on-station trial. The SWC measures however had higher LAI compared to the control treatment which had the least LAI of 5.0. The CR which was about 4.7% more than the FP, had LAI of 5.2 whilst the CR and HM respectively had 5.2 and 5.0 LAI which are about 4.4% and 0.4% more than the LAI of the FP.

The effect of the SWC measures treatments on LAI in the Northern Region was not significant either. Treatments of the SWC measures had higher LAI than the control which had the least LAI of 5.3. The CR had LAI of 5.5 which is about 3.8% more compared to the FP whilst the CF and HM had 5.5 and 5.5 which are about 3.0% and 2.2% more than the FP respectively.

There was significant difference in LAI among the treatments in the Upper East Region trial. All the SWC measures had greater LAI than the control treatment. The CF recorded a LAI index of 5.2 which is about 36.1% more than the FP which had a LAI of 3.8. The CR and the HM had LAI of 5.0 and 5.0 which are about 30.8% and 29.8% more than the FP respectively. Ramesh and Rathika (2009) similarly reported that, conservation of rain water through land configuration techniques such as compartmental bunding, ridges and furrows and tide ridging have considerably improved plant growth parameters like leaf area index. The performance of the SWC measures (CF, HM and CR) over the FP treatment in terms of LAI may be associated with increased soil moisture content in the SWC measures. The higher LAI observed in the SWC measures over the control could also be a factor for the high performance of the SWC measures on growth and yield components of the maize plant because the higher the LAI the greater the photosynthetic effect of the leaves.

The Northern Region recorded higher mean values than the Upper East in terms of LAI. Averagely the Northern Region had a LAI of 5.5 being about 14.5 % more in LAI than Upper East Region which had an average LAI of 4.8. This result may be due to favourable climatic and soil conditions in the Northern Region compared to the Upper East Region.

5.2.6 Effect of soil and water conservation measures on maize root biomass

Effect of treatments on root biomass was significant for the on-station trial. All the SWC measures had higher root biomasses compared to the control. The CF recorded a root biomass of 30.8 g i.e. about 40.7% more than the FP which had a root biomass of 21.9 g. The HM and CR were about 30.8%, and 29.7% more than the FP with root biomasses of 30.8 g and 28.7 g respectively. A similar observation was made by Ramesh and Rathika (2009) who reported that, conservation of rain water through compartmental bunding, ridges, furrows and tide ridging considerably improved plant growth parameters like root growth under rain fed conditions.

There was no significant effect of treatments on maize root biomass for the Northern Region trial. The SWC measures however recorded higher mean values than the control. The CF had a root biomass of 30.6 g i.e. about 23.9% more than the FP which had the least root biomass of 24.7 g. The CR and HM had 27.6 g and 26.4 g which are about 11.7% and 6.9% more than the FP. No significant effect of treatments on root biomass was observed in the Upper East Region. The CF had a root biomass of 25.4 g being about 0.9% more than the root biomass of the FP. The CR and HM had root biomasses of 23.8 g and 22.8 g which are about 5.7% and 9.7% respectively less than the FP which had a root biomass of 25.2 g.

The averagely better performance of SWC measures over the FP could be due higher soil moisture in the SWC measures compared to the control (FP). The significant effect of the SWC measures on the root biomass could also be one of the factors for the higher performance of the SWC measures on growth and yield components of the maize crop. The Northern Region recorded higher root biomasses than Upper East Region. On the average, Upper East Region had a root biomass of 24.3 g and Northern Region had an average root biomass of 27.3 g which is 11.1% more than the Upper East.

5.2.7 Effect of soil and water conservation measures on maize grain yield

The results for SWC practices effect on grain yield for maize in the on-station trial revealed significant difference among the treatments. Grain yield increased considerably under all SWC measures compared to the control. The CF yielded 2.2 t ha^{-1} of maize which is about 102.9% more than the FP which yielded 1.1 t ha^{-1}. The HM and CR yielded 1.9 t ha^{-1} and 1.9 t ha^{-1} which are about 80.0% and 74.3 % higher compared to the FP.

There was also a significant effect of treatments on maize yield in the Northern Region. A considerable increase in yield was observed in all SWC measures compared to the control. The CF had a yield of 5.8 t ha^{-1} which is about 57.4% more than the FP. The CR and HM had 5.8 t ha^{-1} and 5.5 t ha^{-1} of yield which are about 56.0% and 48.9% respectively higher in yield compared to the FP which had a yield of 3.7 t ha^{-1}.

Upper East Region also had significant effect of treatments on grain yield in the maize trial. All SWC measures had a significant increase in grain yield compared to the control. The CR had a yield of 5.1 t ha^{-1} which is about 105.7% more than the FP which had a yield of 2.5 t ha^{-1}. The CF and HM had 4.2 t $ha^{-1}$and 3.9 t ha^{-1} which are about 68.7% and 60.2% more than the FP respectively. Similarly, Ramesh and Rathika (2009) also observed improved yield attributes and yield of many field crops in land conservation techniques such as compartmental bunding, ridges and furrows and tide ridging under rain fed conditions. The considerable increase in grain yield among the

SWC measures over the control may be ascribed to higher soil moisture in the SWC measures compared to the control.

Higher grain yields were observed in treatments in the Northern Region Compared to that of the Upper East Region. The Upper East Region on average yielded 3.9 t ha^{-1} of maize and Northern Region yielded 5.2 t ha^{-1} which is about 32.7% more than the yield of Upper East Region. This significant difference in yield between the two regions may be due to better climatic and soil conditions in the Northern Region.

5.3 Farmers' Perception of Soil Erosion

Soil erosion, nutrient depletion and soil structural change are the main forms of land degradation observed in the study area. All the interviewed farmers perceived soil erosion as a problem constraining crop production. They reported that the most important top soil for crop production activity was deteriorating over time due to erosion processes. Hence, they observed frequently how the loss of soil from cultivated fields has been reducing the depth of the topsoil over time increasing the number of stones in their farmlands.

Out of the thirty (30) respondents in each region, 28 in the Upper East and 29 in the Northern Region mentioned cultivating on steep slope as one of the causes of erosion. Considering poor SWC practices also as a cause of soil erosion, 18 and 21 of the respondents in the Upper East and Northern Regions respectively were in agreement. The number of respondents that indicated excessive rainfall as a cause of erosion was 22 and 25 for Upper East and Northern Region respectively. Population pressure as a cause of erosion had 19 and 13 farmers responding for Upper East and Northern Region respectively.

In the Upper East and Northern Region 14 and 21 respondents respectively, agreed to continuous cropping as one of the causes of soil erosion. Deforestation was mentioned by 17 respondents in the Upper East and 19 in the Northern region as one of the causes of erosion. Considering over grazing as a cause of soil erosion, 11 respondent in the Upper East and 9 respondents in the Northern Region agreed. Similar results were observed by Tsegaye and Bekele (2010) who assessed farmer's perception about forms and causes of soil erosion. Almost all of the farmers that either participated in the group discussion or in the interview perceived decline in soil fertility in their farm over time. All the respondents agreed that soil erosion was the major cause of soil fertility decline.

From the survey, most farmers are aware of land degradation particularly soil erosion in both regions. During the field visit, it was observed that all the farmers (100%) in both regions were aware of what soil erosion is about. In the Upper East, 43.3% of the respondents had a poor understanding of soil erosion whilst 40.0% had a good understanding. About 16.7% had a very good understanding of soil erosion. The Northern Region was not different, 40.0% of the respondents had poor understanding about soil erosion whilst 36.7% and 23.3% had a good and very good understanding of soil erosion respectively (Table 4.14).

In the Upper East Region 20.0% had no knowledge of what SWC measures are about. About 53.3% had a poor knowledge whilst 20.0% and 6.7% of the respondents respectively had a good and very good knowledge of SWC measures. Respondents in the Northern Region that had no knowledge about SWC measures were about 10% whilst 46.7%, 40.0% and 3.3% had poor, good and very good knowledge about SWC measures respectively (Table 4.15). Similar results were reported by Tsegaye and Bekele (2010).

Most respondents, rated erosion as a serious problem and mentioned that the rate of soil erosion has been increasing over time. All of them also answered that erosion can be controlled. Farmers' awareness of water erosion was confirmed by statements such as: When there is run-off it damages our crops; appearance of rills, siltation in and stones start on our fields. From these responses, it can be concluded that farmers have good knowledge of erosion as a problem that limits soil productivity.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Soil moisture content was found to be high under the SWC measures in both cowpea and maize cultivation in the on-station trial. Soil moisture under cowpea cultivation was significantly affected by the SWC measures with the CF having more moisture on average compared to the control (FP), followed by the CR and HM respectively. Similar result was observed in the maize cultivation. Amount of soil moisture among the treatments in a decreasing order under the maize cultivations was CF > CR > HM > FP.

In the on-station, SWC treatments had significant effect on cowpea stem girth only. In the Upper East Region SWC treatments had significant effect on cowpea LAI only whilst in the Northern Region, SWC measures significantly affected stem girth, LAI, root biomass and grain yield.

Similar results were observed for the maize trial. SWC treatments at the on-station had significant effect on plant height, stem girth, root biomass and grain yield. In the Upper East Region, the SWC treatments were observed to have significant effect on height, LAI and grain yield whilst in the Northern Region, significant SWC treatments effect was observed on grain yield only. Altogether the SWC treatments have a greater effect on maize compared to cowpea.

At least 80% and 90% of respondents in the Upper East and Northern Regions respectively were aware of SWC measures as an erosion control measure. The farmers identified the cause of soil erosion in a decreasing order as: cultivation on steep slopes, excessive rainfall, population pressure, poor SWC measures, deforestation and continuous cropping.

6.2 Recommendations

- The study showed that SWC practices enhanced yield of maize in all the selected communities of the study. Therefore farmers in the Northern and Upper East Region should adopt SWC measures for maize cultivation

- The trial should be repeated for confirmation and to further investigate mechanisms by which runoff reduction occurs in SWC measures. This should include the determination of soil and nutrient loss under the conservation measures

- Further studies should take into account the cost-benefit analysis

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APPENDICES

Appendix 1A

Upper East Region ANOVA tables for cowpea cultivation

Analysis of variance table for cowpea plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.327	0.663	0.25	
Block.*Units* stratum					
Trtment	3	16.277	5.426	2.08	0.204
Residual	6	15.633	2.606		
Total	11	33.237			

Analysis of variance table for cowpea stem girth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.06020	0.03010	2.07	
Block.*Units* stratum					
Trtment	3	0.06863	0.02288	1.57	0.291
Residual	6	0.08727	0.01454		
Total	11	0.21610			

Analysis of variance table for cowpea number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	75.740	37.870	12.19	
Block.*Units* stratum					
Trtment	3	14.947	4.982	1.60	0.284
Residual	6	18.633	3.106		
Total	11	109.320			

Analysis of variance table for cowpea LAI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.001667	0.000833	0.43	
Block.*Units* stratum					
Trtment	3	0.071882	0.023961	12.32	0.006
Residual	6	0.011667	0.001944		
Total	11	0.085215			

Analysis of variance table for cowpea root biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	2.717E-05	1.358E-05	6.54	
Block.*Units* stratum					
Trtment	3	7.954E-06	2.651E-06	1.28	0.364
Residual	6	1.246E-05	2.077E-06		
Total	11	4.758E-05			

Analysis of variance table for cowpea grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.07482	0.03741	1.50	
Block.*Units* stratum					
Trtment	3	0.00721	0.00240	0.10	0.959
Residual	6	0.14954	0.02492		
Total	11	0.23157			

Appendix 1B

Northern Region ANOVA tables for cowpea cultivation

Analysis of variance table for cowpea plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	28.500	14.250	2.76	
Block.*Units* stratum					
Trtment	3	20.650	6.883	1.33	0.349
Residual	6	31.020	5.170		
Total	11	80.170			

Analysis of variance table for cowpea stem girth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.304317	0.152158	18.96	
Block.*Units* stratum					
Trtment	3	0.240825	0.080275	10.00	0.009
Residual	6	0.048150	0.008025		
Total	11	0.593292			

Analysis of variance table for cowpea number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	92.92	46.46	4.10	
Block.*Units* stratum					
Trtment	3	100.69	33.56	2.96	0.119
Residual	6	67.98	11.33		
Total	11	261.59			

Analysis of variance table for cowpea LAI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.046638	0.023319	4.81	
Block.*Units* stratum					
Trtment	3	0.101602	0.033867	6.98	0.022
Residual	6	0.029100	0.004850		
Total	11	0.177340			

Analysis of variance table for cowpea root biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.756E-05	8.778E-06	7.18	
Block.*Units* stratum					
Trtment	3	1.803E-05	6.009E-06	4.92	0.047
Residual	6	7.333E-06	1.222E-06		
Total	11	4.292E-05			

Analysis of variance table for cowpea grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.00026	0.00013	0.01	
Block.*Units* stratum					
Trtment	3	0.32854	0.10951	7.34	0.020
Residual	6	0.08946	0.01491		
Total	11	0.41827			

Appendix 1C

On-station ANOVA tables for cowpea cultivation

Analysis of variance table for cowpea plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	113.506	37.835	6.19	
Block.*Units* stratum					
Trtment	3	64.283	21.428	3.50	0.063
Residual	9	55.045	6.116		
Total	15	232.833			

Analysis of variance table for cowpea stem girth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.33327	0.11109	2.12	
Block.*Units* stratum					
Trtment	3	0.64567	0.21522	4.10	0.043
Residual	9	0.47223	0.05247		
Total	15	1.45117			

Analysis of variance table for cowpea number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	212.34	70.78	2.74	
Block.*Units* stratum					
Trtment	3	203.60	67.87	2.62	0.115
Residual	9	232.78	25.86		
Total	15	648.72			

Analysis of variance table for cowpea LAI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.021524	0.007175	1.15	
Block.*Units* stratum					
Trtment	3	0.054093	0.018031	2.88	0.095
Residual	9	0.056317	0.006257		
Total	15	0.131934			

Analysis of variance table for cowpea root biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	6.472E-06	2.157E-06	0.31	
Block.*Units* stratum					
Trtment	3	5.868E-05	1.956E-05	2.82	0.099
Residual	9	6.235E-05	6.928E-06		
Total	15	1.275E-04			

Analysis of variance table for cowpea grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.04552	0.01517	0.38	
Block.*Units* stratum					
Trtment	3	0.39863	0.13288	3.30	0.072
Residual	9	0.36242	0.04027		
Total	15	0.80657			

Appendix 2A

Upper East Region ANOVA tables for maize cultivation

Analysis of variance table for maize plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	25.39	12.70	1.10	
Block.*Units* stratum					
Trtment	3	224.07	74.69	6.49	0.026
Residual	6	69.03	11.50		
Total	11	318.49			

Analysis of variance table for maize stem girth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.0241	0.0120	0.08	
Block.*Units* stratum					
Trtment	3	1.3025	0.4342	2.74	0.136
Residual	6	0.9506	0.1584		
Total	11	2.2772			

Analysis of variance table for maize number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.10667	0.05333	0.65	
Block.*Units* stratum					
Trtment	3	0.24667	0.08222	1.00	0.455
Residual	6	0.49333	0.08222		
Total	11	0.84667			

Analysis of variance table for maize LAI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.15167	0.07583	0.87	
Block.*Units* stratum					
Trtment	3	3.54312	1.18104	13.58	0.004
Residual	6	0.52167	0.08694		
Total	11	4.21645			

Analysis of variance table for maize root biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.00001702	0.00000851	0.73	
Block.*Units* stratum					
Trtment	3	0.00001425	0.00000475	0.40	0.755
Residual	6	0.00007039	0.00001173		
Total	11	0.00010166			

Analysis of variance table for maize grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.0031	0.0016	0.01	
Block.*Units* stratum					
Trtment	3	10.4525	3.4842	13.01	0.005
Residual	6	1.6073	0.2679		
Total	11	12.0629			

Appendix 2B

Northern Region ANOVA tables for maize cultivation

Analysis of variance table for maize plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1092.0	546.0	4.86	
Block.*Units* stratum					
Trtment	3	1350.5	450.2	4.01	0.070
Residual	6	673.5	112.3		
Total	11	3116.0			

Analysis of variance table for maize stem girth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.4198	0.7099	1.59	
Block.*Units* stratum					
Trtment	3	1.1657	0.3886	0.87	0.507
Residual	6	2.6826	0.4471		
Total	11	5.2681			

Analysis of variance table for maize number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.3467	0.1733	1.38	
Block.*Units* stratum					
Trtment	3	0.0467	0.0156	0.12	0.943
Residual	6	0.7533	0.1256		
Total	11	1.1467			

Analysis of variance table for maize LAI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.2487	0.1243	0.89	
Block.*Units* stratum					
Trtment	3	0.0704	0.0235	0.17	0.914
Residual	6	0.8338	0.1390		
Total	11	1.1529			

Analysis of variance table for maize root biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.00002452	0.00001226	0.93	
Block.*Units* stratum					
Trtment	3	0.00005499	0.00001833	1.39	0.334
Residual	6	0.00007926	0.00001321		
Total	11	0.00015877			

Analysis of variance table for maize grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.04201	0.02100	0.23	
Block.*Units* stratum					
Trtment	3	9.10871	3.03624	33.52	<.001
Residual	6	0.54355	0.09059		
Total	11	9.69427			

Appendix 2C

On-station ANOVA tables for maize cultivation

Analysis of variance table for maize plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	1906.77	635.59	10.73	
Block.*Units* stratum					
Trtment	3	1663.31	554.44	9.36	0.004
Residual	9	533.27	59.25		
Total	15	4103.35			

Analysis of variance table for maize stem girth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	6.43010	2.14337	39.23	
Block.*Units* stratum					
Trtment	3	3.06210	1.02070	18.68	<.001
Residual	9	0.49170	0.05463		
Total	15	9.98390			

Analysis of variance table for maize number of leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.14188	0.04729	0.49	
Block.*Units* stratum					
Trtment	3	0.35187	0.11729	1.21	0.362
Residual	9	0.87563	0.09729		
Total	15	1.36937			

Analysis of variance table for maize LAI

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.84633	0.28211	4.98	
Block.*Units* stratum					
Trtment	3	0.18871	0.06290	1.11	0.394
Residual	9	0.50942	0.05660		
Total	15	1.54446			

Analysis of variance table for maize root biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	3.603E-05	1.201E-05	4.34	
Block.*Units* stratum					
Trtment	3	1.779E-04	5.931E-05	21.42	<.001
Residual	9	2.492E-05	2.769E-06		
Total	15	2.389E-04			

Analysis of variance table for maize grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	3	0.64991	0.21664	2.42	
Block.*Units* stratum					
Trtment	3	2.73698	0.91233	10.20	0.003
Residual	9	0.80526	0.08947		
Total	15	4.19215			

Appendix 3

Questionnaire

Soil and Water Conservation Trial 2014

This questionnaire has been prepared to generate information on the extent of the farmers' knowledge about erosion and SWC technologies as well as factors that causes erosion.

Name of farmer ---Sex----------- age -------------

Region--------------------------------------Community----------------------------Date------------**Part One**

Closed questions

Farmers' perceptions of soil erosion

1. Do you know soil erosion? A/ yes B/ no
2. How well do you know about soil erosion? (grade yourself from 1-3)
3. A/Low B/Moderate C/ Strong
4. Is soil erosion a problem in your farm? A/ yes B/ no
5. If yes, what is the severity of the problem? (grade severity from 1-3)
6. A/PoorB/ Good C/ Very good
7. You believe that the rate of erosion over time is, A/ increasing B/ same C/decreasing
8. What do you believe is the impact of soil erosion on crop yield? A/ large decrease B/ moderate decrease C/ no change D/ moderate increase E/ large increase
9. Do you believe that soil erosion can be controlled A / yes B/ no
10. Which factors do you think are the main causes of soil erosion on your farm?
    A/ Cultivation on steep slopes B/ Excessive rainfall
    C/ Population pressure D/ Poor SWC practices
    E/ Continuous cropping F/ Deforestation
    G/ Over grazing

Farmers' knowledge of SWC measures

11. Do you know SWC measures? A/ yes B/ no
12. How well do you know SWC measures? (grade yourself from 1-3)
    A/ Poor B/ Good C/ Very good
13. Do you believe that the SWC technologies have the potential to improve land productivity? A/ yes B/ no
14. Do you have plan/intention to adopt SWC technologies? A/ yes B/ no
15. If no why…………………………………………………………………………………

……………………………………………………………………………………………..

16. What are the major limitations to apply SWC measures on your farm land?
    A/ The technologies require too much labor to implement
    B/ Land tenure insecurity
    C/ Decrease the size of crop land
    E/ Lack knowledge
    F/ Not considering erosion as a major problem
    G/Others ---

Part two

Open Ended Questions

1. What are the major crops you grow on your farmland?

----

2. Do you have a problem of erosion in your farm? ---
----

3. How do you know soil erosion occurs on your farm land? (Indicators) ----------------
----

----

4. Why don't you apply SWC measures on your farm?

----

5. Have you ever discussed the issue with your fellow farmer and draw potential solutions?
----------------- If yes,

i. what were the problems? ---

----

ii. what were the potential solutions?---

----

6. How do you protect your farmland from erosion? (List all methods you apply) ------
----

----

7. Are methods you apply effective? --
----

8. Do you know about SWC technologies? ---
----

9. Have you ever participated in SWC technology demonstration, field days or workshops before? ---
----