# Effect Of Soil And Water Conservation Methods On Maize Performance And Soil Water Retention In Northern Region Of Ghana

Eliasu Salifu, Wilson Agyei Agyare, Asamoah Larbi

**Abstract**: Farmers in the Northern Region of Ghana are mostly smallholder farmers. They are continuously confronted with erratic rainfall and land degradation as a result of poor agronomic practices. Soil and Water Conservation (SWC) methods are interventions that can be put in place to limit soil loss and sustain soil moisture in areas where there is inadequate moisture and the risk of losing the valuable topsoil. In the 2014 cropping season, an on-farm experiment was conducted in the Region to assess the effect of SWC methods [Contour Farming (CF), Half Moon (HM), Contour Ridges (CR) and Flat Land (FL)] on soil moisture content at the root zone, growth components and yield of maize. There was a significant effect of the SWC methods on soil moisture at the root zone of maize at a probability (P) value of 0.00181. The CF retained the most soil moisture at the root zone with an average volumetric soil moisture of 18.4%. This was followed in decreasing order by CR (18.1%), HM (17.8%) and the FL (16.8%). The SWC methods significantly affected maize height (P = 0.0112), stem (P = 0.0174), root biomass (P = 0.035) and grain yield (P = 0.00578). Considering the higher soil moisture retention and yield under CF, it is recommended as the best option among the studied methods for SWC in Northern Region of Ghana.

**Keywords**: Soil and Water Conservation Methods, Half Moon, Contour Ridges, Contour Farming, Flat lands, Maize.

## 1 Introduction

Major challenge facing farming households, agricultural communities, governments and development agencies in the developing world is how to increase agricultural production while sustaining the productive capacity of the land [1]. Ghana's economy continues to be heavily dependent on agriculture and the critical challenge that remains is how to increase agricultural output while at the same time maintaining the natural resource base supporting agricultural production [2]. According to [3], growth in the country's agricultural sector is mainly attributed to land area expansion as opposed to yield increases. With regard to climate change scenarios, agricultural production must increase significantly in ways that are sustainable and acceptable by rural smallholders [4]. To achieve this potential requires that the declining soil quality conditions be addressed through the use of conservation methods with the aim to reduce losses, sustain resources and enhance productivity. Majority of small holder farmers in the Northern Region of Ghana are maize farmers that are exposed to rapid soil degradation, hence there is a failure of production to keep pace with the increase in population. According to [5], the potential of maize crop has not been realized so far, as there is a large gap between potential and actual yield per acre. Conservation methods such as contour farming have therefore been encouraged among small scale farmers in the region but adoption however is low among farmers as they continue to use the traditionally unproductive approach of ploughing along slopes that promotes soil degradation and low yields.


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Against this background, governmental and non-governmental organizations in Northern Ghana are engaged in promoting soil and water conservation practices among farmers so as to increase agricultural productivity in the area [2]. Soil erosion in most farm lands in northern Ghana is visible. Most cultivated lands in these areas have suffered from loss of top soil, leaving bare ground devoid of soil nutrients. Studies on SWC methods done in the northern part of Ghana shows improved crop yields under SWC methods compared with usual farm practices. It has been reported by [6] of improved yields of maize, sorghum, millet, rice and groundnut under SWC methods compared farmer practice in Bawku municipality of the Upper East Region. Kiran and Lingaraju [7] reported higher soil moisture among in-situ moisture conservation practices such as ridges, furrows and compartmental bunding compared to flat land. The study was carried out to determine the effect of contour farming (CF), half-moon (HM), contour ridges (CR) and flat land (FL) soil and water conservation (SWC) methods on soil moisture content at root zone of maize as well as on the growth and yield components in the Northern Region of Ghana.

## 2 Materials and Methods

### 2.1 Study Area

The study was carried out in the Northern Region of Ghana (Fig.1) which covers an area of 70,384 km$^2$ and occupies 30% of the country. It comprises sub−humid to semi−arid guinea and sudan savannah [8]. The region is characterized by a single rainy season that begins in May and ends in October with a mean annual rainfall of about 1100 mm. The soils are mainly savanna ochrosols and groundwater lateritic soils. The study was restricted to four communities in the region with relatively similar agro-ecological conditions and farming system characteristics in terms of implements, farming practices and crop types. The communities were Duko (9° 33' 47.376'' N, 0° 49' 48.18'' W), Kogni (9° 32' 57.912'' N, 0° 51' 26.352'' W), Tingoli (9° 20' 3.48'' N, 1° 2' 49.308'' W) and Gbanjon (9° 27' 13.068'' N, 1° 6' 2.8944'' W).

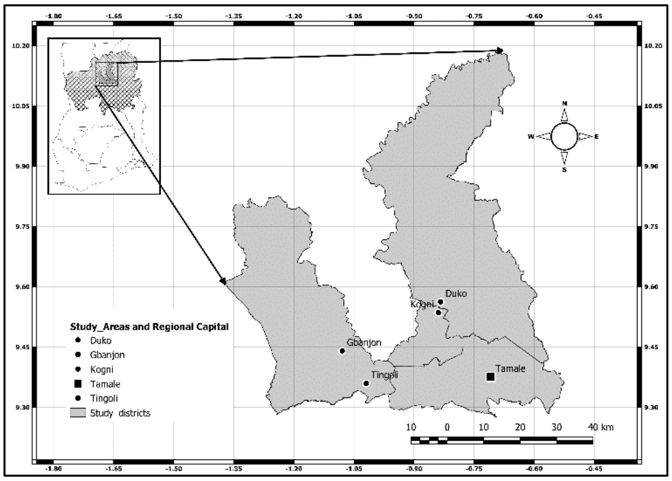


***Fig. 1**: Map of Northern Region of Ghana showing study areas*

## 2.2 Experimental Design and Treatment Implantation

The experiment was a single season experiment conducted in the 2015 farming season under rain fed conditions. The trials were carried out in 4 different locations with each location serving as an experimental replication, thus functioning as an experimental block. Though the experiments were conducted on farm in collaboration with farmers, there was a uniform protocol to ensure unvarying application of field operations and treatments as well as monitoring. The following soil and water conservation methods were applied as treatments in each location. Contour Farming (CF), Half Moon (HM), Contour Ridges (CR) and Flat Land (FL). The treatments were applied in a Randomized Complete Block Design (RCBD) with a plot dimension of 5×10 m with a 1m alley between plots. Slopes were determined for each experimental site and land ploughed and harrowed to evenly distribute the soil. An 'A' frame was used to determine contour lines to enable the setting up of contour plots. The CR were made up of 20 cm high earth ridges parallel to each other at 2 m interval along the contour. This resulted in a total of five (5) ridges on each CR plot. The HM were made up of 20 cm high semi-circular bunds with 2 m diameter laid in staggered manner with their tips on the contours thus resulting in 8 bunds. There was a 1 m gap between neighbouring bunds to allow water to flow down slope to the next bund. The CF, ridges were laid parallel and along the contours to enable sowing and other farm activities to be done along. The standard and recommended spacing of 75 cm was applied between ridges thereby yielding thirteen (13) ridges for CF plot. The FL plot was ploughed, harrowed along the slope and left bare as it is the common practice among farmers in the study area.

## 2.3 Planting and Crop Management

The Omankwa maize variety which is average yielding with a medium duration (90 days) was used for the trial. The seed was planted with a dibbler at 75 cm row spacing and 40 cm inter-row spacing with 2 seeds per hill thereby yielding a plant population of 135200 ha$^{-1}$. Pre-emergence weed control was applied on the planting day using 'Activus 500 EC (Active ingredient: Pendimenthalin 500g/L). Fourteen (14) Days After Sowing (DAS), the first weeding was done manually with a hoe. The second weeding was done 35 DAS. The N.P.K 15.15.15 fertilizer was applied to the maize 14 DAS at the recommended application rate of 5g per hill (i.e. 100 g ha$^{-1}$) whilst Sulphate of Ammonia was applied 28 DAS at the recommended rate of 2.5g per hill (i.e. 50 kg ha$^{-1}$). The various conservation methods were reshaped 20 DAS due to the effect of rainfall and runoff.

## 2.4 Data Collection

Primary and secondary data were collected from the field and agricultural offices respectively. In order to have representative soil sample, composite samples were taken to laboratory for analysis to determine the physiochemical properties of the soil in each study area. Data on the effect of SWC methods on soil moisture at the root zone, growth and parameters of maize were collected. Data on the plant growth parameters were taken from five sampled plants diagonally on each experimental plot. Rainfall data over the period of study (Fig. 2) was also collected.

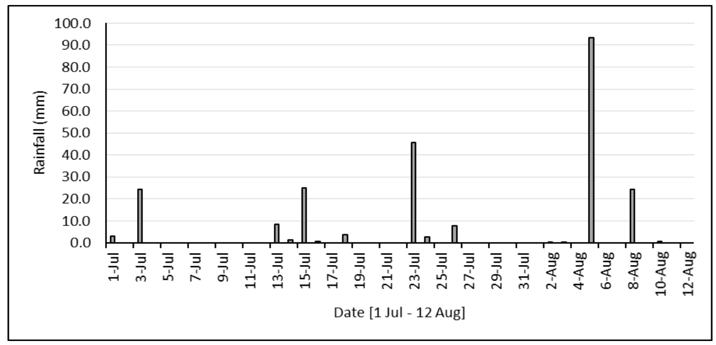


***Fig. 2**: Average rainfall in study area*

### 2.4.1 Soil moisture content at root zone

Soil moisture at the root zone of maize was collected with 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 16 cm long metals pinned into the soil. The probe measures the moisture in the soil which is displayed as volumetric soil moisture content. Ten soil moisture measurements were made on each plot through the experiment at three days intervals starting from 14 DAS.

### 2.4.2 Plant height and stem girth

Maize plant height and stem girth were taken at 50% tasseling in cm. A calibrated wooden rule was used to measure the plant height from the ground level to the tassel whilst a caliper was used to measure the stem girth between the first and second node of the maize plant.

### 2.4.3 Leaf number and area index

The number of leaves of the plants were obtained by directly counting the functional leaves on sampled plants at 50% tasseling. The length and width of the leaves were measured with a rule to determine the area as in Eq. (1). The leaf rea (LA) was then used to calculate for the leaf area index (LAI) as shown in Eq. (2).

$$LA = L \times W \times r \qquad \text{Eq. (1)}$$

$$LAI = \frac{LA}{A} \qquad \text{Eq. (2)}$$

Where LAI = Leaf Area Index

LA = Leaf Area
L = Leaf length
W = leaf width
r = Correction factor (0.75) as proposed by [10]
A = Area leaf occupies

### 2.4.4 Root biomass
The root biomass was determined at 50% tasseling of the maize crop. Five plants samples on each plot were carefully removed with a cylindrical ring to ensure all roots were intact. The stems were cut off from the roots which were then oven dried at a temperature of 62$^{O}$ C for 48 hours and then weighed to obtain the dry weight.

### 2.4.5 Grain yield
Yield of maize was taken 90 DAS from the two middle rows of each plot. The grains were then dried to about 12% moisture content and weighed. The grain weight was then converted from kg to tonnes per hectare (t ha$^{-1}$) using the relationship in Eq. (3).

$$Yield\ (t\ ha^{-1}) = \frac{yield\ (kg)}{3.75m^2} \qquad \text{Eq. (3)}$$

Where 3.75m$^2$ = Area of two rows

### 2.5 Data Analysis
The R Studio data analytical software version 3.4.4 was used to analyze the data. Analysis of Variance (ANOVA) was used to determine effect of the SWC methods on soil moisture content at the root zone, as well as the growth and yield parameters of the maize crop at a significance level of 5%. Tukey HSD (Honest Significant Difference) was used to compare and separate treatment means.

## 3 Results and Discussions

***Table 1**: Soil chemical properties in study areas*

| | Communities | | | |
|---|---|---|---|---|
| **Properties** | **Kogni** | **Duko** | **Tingoli** | **Gbanjon** |
| Organic carbon (%) | 0.84 | 0.81 | 0.59 | 0.53 |
| Organic matter (%) | 1.44 | 1.4 | 1.02 | 0.91 |
| Total N (%) | 0.13 | 0.11 | 0.12 | 0.13 |
| pH | 4 | 6.37 | 5.99 | 6.62 |
| K | 0.15 | 0.19 | 0.08 | 0.08 |
| Na | 0.21 | 0.13 | 0.04 | 0.04 |
| Ca | 5.48 | 3.2 | 2.94 | 2.14 |
| Mg | 0.88 | 0.53 | 1.07 | 0.27 |

***Table 2**: Soil physical properties in study areas*

| | Communities | | | |
|---|---|---|---|---|
| **Properties** | **Kogni** | **Duko** | **Tingoli** | **Gbanjon** |
| Infiltration rate(cm h-1) | 2.18 | 1.22 | 1.33 | 1.73 |
| Slope (%) | 4.1 | 4.5 | 5.1 | 4.8 |
| Sand (%) | 54.3 | 50.2 | 68.6 | 57.4 |
| Silt (%) | 24.7 | 39.4 | 11 | 34.6 |
| Clay (%) | 12.8 | 10.4 | 20.4 | 8 |
| Texture | Sandy loam | Loam | sandy loam | Sandy loam |

### 3.1 Soil moisture content at root zone
There was significant effect (P = 0.00181) of treatments (SWC methods) on soil moisture content at the root zone of maize as shown in Fig 3. The CF (18.4%) had the most volumetric soil moisture content. This was followed in a descending order by CR (18.1%), the HM (17.8%) and the FL (16.8%) which had the least volumetric soil moisture content. Fig. 4 shows the volumetric soil moisture for the SWC methods at the different days of moisture readings. It can be seen that CF was dominant in four cases of the moisture readings i.e. at 14 DAS, 23 DAS, 26 DAS and 32DAS. The CR was also dominant on four occasions i.e. at 17 DAS, 20 DAS, 29 DAS and 35 DAS. The HM and FL were dominant on 41 DAS and 38 DAS respectively. It is noticeable by observing the rainfall and soil moisture data that volumetric soil moisture at the root zone increases with rainfall with all SWC methods. However the level of moisture retained varied across the SWC methods depending on their structure and other physical properties of the soils.

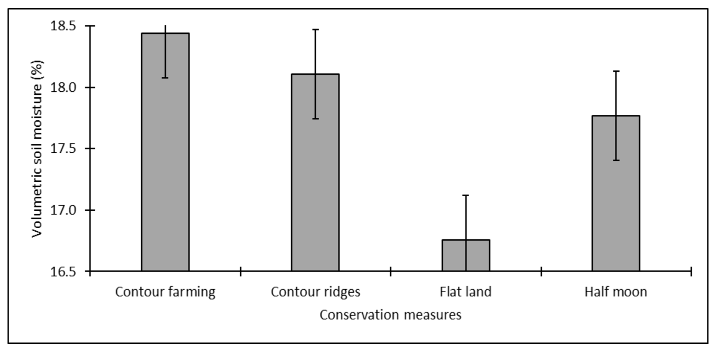


***Fig. 3**: Soil and water conservation methods effect on soil moisture content at maize root zone*

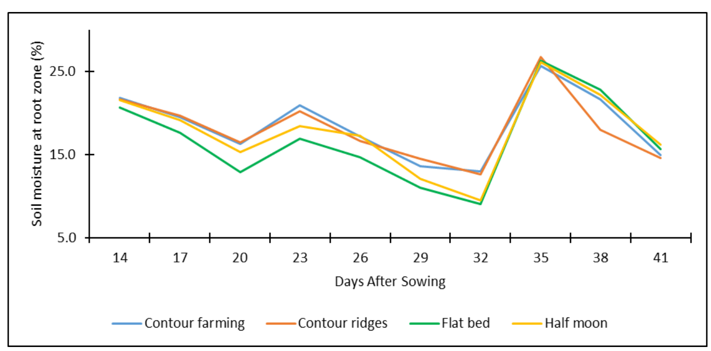


***Fig. 4**: Soil and water conservation methods effect on soil moisture content variation at different Days After Sowing*

### 3.2 Height
Analysis of variance showed significantly (P = 0.0112) taller maize plants in the conservation methods (CF, HM and CR) compared to the FL as shown in Fig. 5. This observation is similar to the study by [11] who observed taller sorghum on

ridges and furrows with the lowest heights observed on flat land. Ramesh and Rathika [12] also observed significant plant height in the conservation of rain water through land configuration methods such as compartmental bunding, ridges and tide ridging. The CF had the highest height of 185.0 cm which is 35% higher compared to the FL which had the least height of 119.3 cm. The CR and HM were 32% and 27% higher than the FL with heights of 175.7 cm and 162.9 cm respectively.

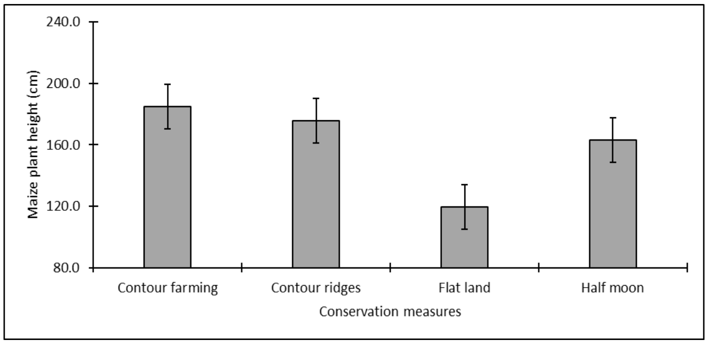


***Fig. 5**: Maize plant height at tasseling*

### 3.3 Stem Girth

There was significant difference at (P = 0.0174) in treatment means among the conservation methods compared to the FL on stem girth as shown in Fig. 6. The CR (6.7 cm) was 24 % bigger than the FL whilst the CF (6.5 cm) was 21% more compared to the FL. The HM (6.4 cm) was 20% compared to the FL.

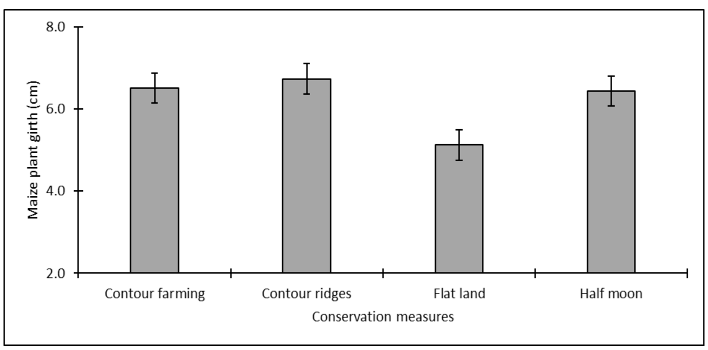


***Fig. 6**: Maize stem girth at tasseling*

### 3.4 Number of Leaves

Insignificant treatment means were observed on maize number of leaves at (P = 0.547) for the maize crop as shown in Fig. 7. This observation is in contrast to a study by [13] who observed significantly higher number of functional leaves per plant in ridges and furrow methods of moisture conservation compared to other practices.The soil conservation methods (CF, CR and HM) however performed better than the FL. Both CF and CR had average number of leaves of 10.8. This was followed by HM with 10.4 and the FL had 10.1 average leaves.

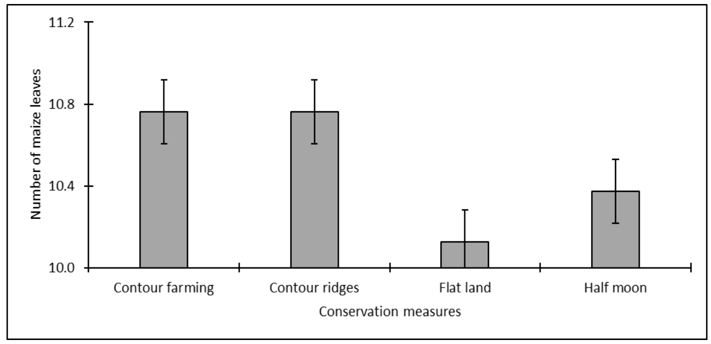


***Fig. 7**: Number of maize leaves at tasseling*

### 3.5 Leaf Area Index (LAI)

Effect of the different conservation methods on LAI of the maize is presented in Fig. 8. There was no significant treatment effect (P = 0.727) of treatments on LAI. However, conservation methods had higher LAI compared to FL which had the least LAI of 5.79. The CR which was 4.5% more than the FL, had LAI of 6.07 whilst the HM and CF respectively had 6.06 and 6.00 LAI which are 4.4% and 3.5% more than that of the FL. A similar study conducted by [12] observed significant effect of land conservation methods such as compartmental bunding, ridges and furrows and tide ridging on LAI.

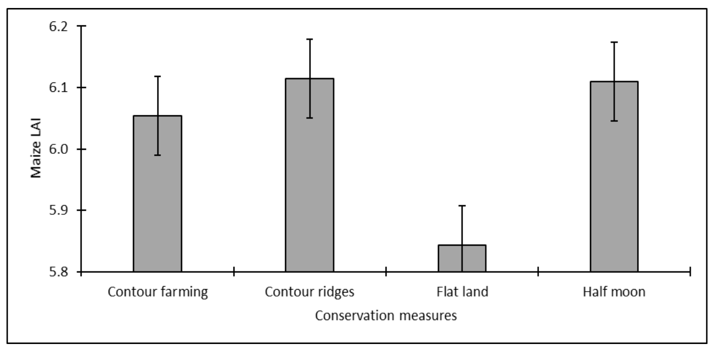


***Fig. 8**: Maize LAI at tasseling*

### 3.6 Root Biomass

Influence of the SWC methods on root biomass of maize is presented in Fig. 9. Analysis of variance at (P = 0.035) showed significant difference between the treatments. The CF recorded a root biomass of 28.1 g i.e. 20% more than the FL which had a root biomass of 22.5 g. The CR and HM were 19% and 17% more than the FL with root biomasses of 27.8 g and 27.0 g respectively. A similar observation was made by [12] who saw significant root growth on compartmental bunding, ridges, furrows and tide ridging under rain fed conditions.

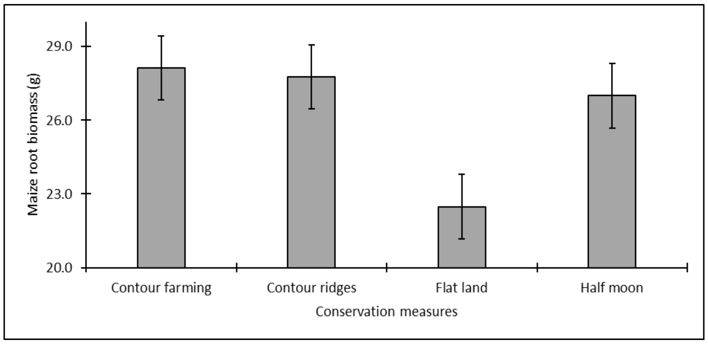


***Fig. 9***: *Maize root biomass at maturity*

### 3.7 Grain Yield
Maize grain yield was significantly (P = 0.00578) higher for the conservation methods compared to the FL as shown in Fig. 10. The CF yielded 5.71 t $ha^{-1}$ of maize which is 21% more compared to the FL which yielded 4.48 t $ha^{-1}$. This was followed in a descending order by CR and HM which respectively yielded 5.53 t $ha^{-1}$ and 5.10 t $ha^{-1}$ which are 19% and 12% more compared to the FL. A similar observation was made by [12] who observed improved yields of many field crops in soil and water conservation methods such as ridges, furrows and tide ridging under rain fed conditions.

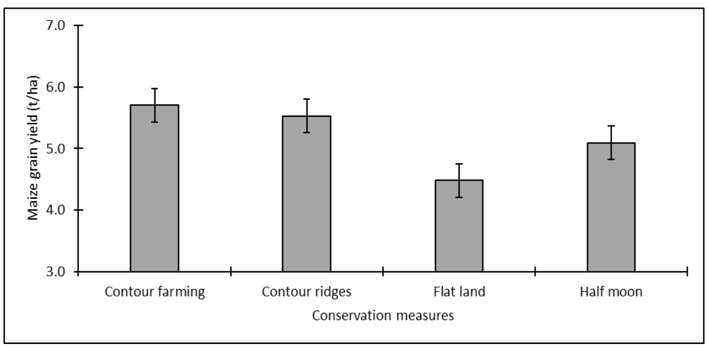


***Fig. 10***: *Maize grain yield at harvest*

## 4 Conclusions
The study found soil moisture to be higher under the soil and water conservation methods (CF, CR and HM) compared to the farmer practice (FL). Similarly, the conservation methods improved growth and yield parameters of maize. There was significantly higher maize height, stem girth and root biomass at the tasseling stages of the maize for the SWC methods. The effect was also significant on maize grain yield at harvest.

## Recommendations
The SWC methods especially CF is recommended for the cultivation of maize in the Northern Region of Ghana due to its high performance in terms of soil water retention and yield of maize. For the essence of validation and confirmation purposes, the experiment should be repeated whilst taking in to account the quantification of soil loss and the cost-benefit analysis to determine its economic viability and adoptability

## References

[1] Mgbenka, R.N. (2012). Soil and water conservation capabilities among farmers and extension agents in eastern region of Nigeria', African Journal of Agricultural Reseearch, 7(1), p. 58–67.

[2] Nkegbe, P. K. (2018). Soil and water conservation practices and smallholder farmer multi-activity technical efficiency in northern Ghana, Ghana Journal of Development Studies. Faculty of Integrated Development Studies, University for Development Studies, Ghana, 15(1), p. 55.

[3] MoFA, (2007). Food and Agriculture Sector Development Policy (FASDEP II).

[4] Lemoalle, J. (2007). Global trends in the Volta basin. Volta Basin Focal Project Report No 3, Montpellier: IRD, and Colombo: Challenge Program for Water and Food (CPWF), p. 26.

[5] Khan, M.A., Marwat, K.B., Khan, N. and Khan, I.A. (2003). Efficacy of different herbicides on the yield and yield components of maize. Asian Journal of Plant Science, 2: p. 300-304.

[6] Senayah, J.K., Kufogbe, S.K. and Dedzoe, C.D. (2001). Land Degradation in the Sudan Savanna of Ghana : A Case Study in the Bawku Area.

[7] Kiran, J.A. and Lingaraju B.S. (2004) Effect of in-situ moisture conservation practices and nitrogen level on growth and yield of rabi sorghum. Karnataka Journal of Agricultural Sciences, 18 (27), p. 214-296.

[8] Bidzakin, J. K. and Fialor, S. C. (2014). Small Scale Maize Production in Northern Ghana. 9 (2), p. 76–83.

[9] Kveˇt, J. and Marshall, J. K. (1971). Assessment of leaf area and other assimilating plant surfaces. Plant photosynthetic production: manual of methods, p. 517–555.

[10] Munish, K., Singh, R.A. and Singh, S.P. (2008). Performance of moisture conservation practices and levels of nitrogen on sorghum under rainfed ecosystem of central Uttar Pradesh. Indian. Journal of Soil Conservation, 36: p. 22-23.

[11] Ramesh, T. and Rathika, S. (2009). Land configuration techniques for rain fed Alfisols ecosystem- review. Green Farming 2 (12), p. 879-881.

[12] Taley, S. M., Pongde, S. M. and Ubarhande, V. P. (2014). Evaluation of in-situ soil and moisture conservation methods on runoff, soil and nutrient loss and productivity of jowar crop. Periodic Research, 3: p. 186-189.