THE IMPACT OF DIFFERENT TILLAGE AND SOIL AMENDMENTS ON SOIL MOISTURE STORAGE, EROSION AND THE YIELD OF MAIZE IN THE MOIST SEMI-DECIDUOUS FOREST ZONE OF GHANA

BY

GINETTE DEMBELE

(ENGINEER IN AGRONOMY)

AUGUST, 2015

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MASTER OF PHILOSOPHY

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BY

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DECLARATION

I, hereby declare that this submission is my own work toward the Mphil degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree by the University, except where due acknowledgment has been made in the text.

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DEDICATION

This project work is dedicated to my Father Antoine Tontigui Dembélé and my Mother Catherine Dembélé, my Sisters Natasha Maria Martine, Marcelline and her Husband Youssouf Camara, and my Brother Jacques Robert Dembélé and his family for being the artisan of what I am today.

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ABSTRACT

The impact of different tillage practices and soil fertility amendments on soil loss and moisture storage has not received the needed research attention in Ghana. A study was conducted at the KNUST Agricultural Research Station at Anwomaso, Kumasi to evaluate soil moisture storage and erosion under four tillage practices with some soil amendments. This was to recommend the best soil management option for sustainable maize production. The experiment was conducted in 2014 for two consecutive seasons (major and minor) on a sandy loam to sandy clay loam soil (Plinthic Vetic Lixisol). The field layout was split-plot in a randomized complete design with three replications. Tillage practices (no tillage, plough- plant, plough-harrow plant and hoe) constituted the main plot factor and four soil fertility amendments (100% NPK fertilizer (60-60-60 kg ha $^{-1}$) + Urea, Poultry Manure (3 t ha $^{-1}$), ½ Rate of PM/ha (30-30-30 kg ha $^{-1}$) + ½ Rate of NPK Fertilizer (1.5 t ha $^{-1}$) + ½ Rate Urea and Control) were the sub plot factor. Three bare plot plots were included from which runoff and soil loss measurements were made. The tillage practices had significant effects ($P< 0.05$) on runoff and soil loss. The results showed that no tillage, with ½ Rate of PM/ha (30-30-30) + ½ Rate of NPK gave higher agronomic characteristics of maize (grain and stover yield) and produced minimum runoff and soil loss. Soil loss increased with increasing rainfall with coefficient of determination ranging from 0.43 to 0.77 to 0. 63 to 0.74 under tillage practices in the major and minor seasons, respectively. Tillage practices and soil fertility amendments interacted to significantly reduce soil loss and runoff. Combinations of plough-harrow x 100% NPK and hoe tillage x 100% NPK recorded the highest added

benefits of -3.09 and -2.53 respectively in the major season whilst hoe tillage x ½ NPK + ½ PM produced the highest (-7.19) benefit in the minor season.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Maize (*Zea mays L.)* is the most widely-grown staple food crop in Sub- Saharan Africa (SSA) and an important income earner in many countries (Byerlee and Eicher, 1997). In Ghana, it is the most important cereal crop produced and the most widely consumed (FAO, 2008). According to FAO (2011), the area harvested to maize in Ghana in 2009 was 954,400 ha.

The loss of crop productivity through soil degradation implies loss of revenue for the socio-economic development of the country (Bonsu and Quansah, 1992; Amegashie *et al.*, 2012). The major types of degradation responsible for yield loss are soil fertility decline without replenishment, soil erosion and compaction (Lal, 1998; Crawford *et al.*, 2005). Low application of external inputs is another major reason accounting for low crop productivity in maize (Benneh *et al.*, 1990; Adu, 1995). Low soil fertility resulting in low crop yields poses development challenges such as insufficient domestic production, national food insecurity and poverty (Fosu-Mensah, 2012).

According to Weight and Kelly (1999), soil fertility problems in Sub-Saharan Africa (SSA) can be attributed to soil degradation leading to deterioration of soil structure and loss of organic carbon (Lal, 2006), both of which reduce the ability of soils to retain moisture (Lal, 2010). Soil degradation is accelerated through poor soil management options, including inappropriate tillage practices with a consequent reduction in crop yield (Amankwah, 1997). Intensive tillage practices especially in tropical and subtropical climate accelerate soil erosion, cause compaction in the upper soil depth and loss of organic matter (Lupwayi *et al*., 2001). Sivakumar and Wallace (1991) reported that tillage influences crop growth and yield by changing soil structure and moisture removal patterns over the growing season. However, the physical properties of the soil are important for crop growth and the maintenance of soil quality (Rachman *et al*., 2003).

Soil degradation leads to a reduction in soil water holding capacity. Bilgin *et al.* (2008) reported that corn seedlings grow and develop well in 75% available soil water level.

Increasing water deficit tends to have the highest impact on maize yield in the interval between 100 and 300 mm of moisture content (Ceglar *et al.,* 2013). About 20% of the yield gap between actual yields under drought and yield potential can be met by innovative water conservation practices (Muchow, 2000). It is therefore essential to select tillage practices that sustain and enhance the soil physical properties required for successful growth of agricultural crops (Jabro *et al*., 2009).

Through soil compaction and erosion particularly runoff, a major part of rainfall which is needed to fill the soil's moisture reservoir on crop lands is lost. This constrains soil moisture storage on which smallholder farmers depend for crop production (Sivakumar and Wallace, 1991; Mando *et al.,* 1999). These adverse impacts need to be reversed in order to sustain crop growth and yield (Amegashie *et al.,* 2012). Available strategies include the use of tillage to reduce runoff and soil loss, enhance infiltration and soil water storage, crop residue management to reduce evaporation and erosion; and soil amendment to replenish lost nutrient. It is in this context that this study was undertaken to provide relevant data or information especially on soil moisture storage under different tillage practices and soil amendments which is hitherto very scanty.

1.2 General objective

To promote improved maize production through promising land management practices with the most potential for erosion control.

1.3 Specific objectives

The specific objectives were to assess:

i. The effects of no-tillage, hoe-tillage, plough-plant and plough-harrow-plant on soil moisture storage and maize yield;

ii. The effect of fertilizer amendment on soil moisture storage, erosion and maize yield;

iii. And to establish the most promising soil management options for maize production.

1.4 Hypotheses

The above objectives were formulated based on the hypothesis that:

i. Different tillage practices have different impacts on soil moisture storage, runoff, soil loss and maize grain yield.

ii. Different soil amendments have different impacts on soil moisture storage, runoff, soil loss and maize grain yield.

iii. Different interactions of tillage and soil amendment have different impacts on soil moisture storage, runoff, soil loss and maize grain yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soil erosion

Soil erosion is the movement and loss of soil by water, wind or tillage (Kirkby and Morgan 1980). It carries away nutrients that are associated with the soil particles (Karimata, 2001). Soil erosion has been increasing since the beginning of the 20th century (Angima *et al.,* 2003) and has become the most serious form of land degradation in the global perspective (Nanna, 1996). It has been estimated that 75 billion tons of soil is removed due to erosion largely from agricultural lands every year (Pandey *et al.,* 2009). Thus, soil erosion is considered as one of the most critical environmental hazards of modern times (Bahadur, 2008). In economic terms, the consequences can be severe due to a significant reduction in yields (Karimata, 2001).

2.1.1 Soil erosion by water

Water is the most dominant agent of erosion, the process involving detachment, transportation and deposition of individual particles (sediment) by raindrop impact and runoff water (Julien, 2002). Poor land and water management practices and lack of effective planning and implementation approaches for soil conservation are responsible for accelerating degradation on agricultural lands (Yohannes and Herweg, 2000). More than 56% of land degradation is caused by water erosion, raising a global concern on land productivity (Elirehema, 2001).

2.1.1.1 Factors affecting soil erosion by water

Soil erodibility and rainfall erosivity are two important physical factors that affect the magnitude of soil erosion (Lal and Elliot, 1994). Soil erodibility, the resistance of the soil to both detachment and transport, is a function of soil physical characteristics and the management of the soil (Morgan, 1995). The concept of erodibility and how to assess it is complicated since the susceptibility of the soil to erosion is influenced by a large number of properties such as physical, mechanical, hydrologic, chemical, and biological, and soil profile characteristics such as the depth and its influence on vegetative growth (Veihe, 2003).

Rainfall erosivity is the aggressiveness of the rain to cause erosion and is a function of the physical characteristics of rainfall (Morgan, 1995). It has been established that a few, very intense rainfall events are responsible for the largest part of soil erosion and sediment delivery (Gonzalez-Hidalgo *et al.*, 2007). Erosivity is a link between the dynamic properties of rainfall as a consequence of rainfall generating processes and their impact on soil. It is an indication of precipitation aggressivity (Angulo-Martinez and Begueria, 2003). This characteristic of rainfall is a function of its amount, duration, drop size distribution, intensity and kinetic energy. The importance of rainfall erosivity in the assessment of soil erosion risks stems from the fact that, unlike other natural factors that affect soil erosion, the erosive capacity of rainfall is not subject to human modification (Angulo-Martinez and Begueria, 2003).

Soil erosion is strongly affected by many other factors, such as land use/land cover, slope, tillage control measure and soil moisture (Bu *et al.*, 2008). Steep and long slopes in mountain regions enhance soil erosion. Appropriate soil erosion control measures such as engineering, protective cropping (such as contour farming) and biological measures (such as contour hedgerow), by changing the original geomorphology, could reduce the effect of slope on the intensity of erosion (Cai *et al.,* 2005).

2.1.2 Wind erosion

Wind erosion occurs when the soil is dry, loose and bare (Sterk, 1997). The main negative effects of wind erosion can be seen on agriculture, environment and human health (Cornelis *et al.,* 2010). Vegetation cover is a significant factor for protecting the soil surface against erosive wind (Youssef, 2012). Thus, a change in vegetation cover has a direct impact on the quantity and intensity of wind erosion. Vegetation has an ability to decrease soil loss due to wind erosion through the protection of the soil surface (Leenders *et al.,* 2007).

2.2 Effects of erosion

The consequences of soil erosion are generally grouped into on-site and off-site effects.

2.2.1 On-site effects

On-site impact includes a decrease of effective rooting depth, nutrient and water imbalance in the root zone and subsequent decrease in soil quality that leads to reduction in agricultural production (Wang, 2003). Removal of significant amount of plant enriched top soil due to soil erosion results in lowering of soil fertility through the losses of nutrients and organic matter leading to significant decline in crop yield (Lal, 1996).

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 (Ritter, 2012).

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, and necessitates replanting in the affected areas. Also, sediment can accumulate on down-slope properties and contribute to road damage (Ritter, 2012).

Sediment that reaches streams or watercourses can accelerate bank erosion and drainage channels, fill in reservoirs, damage fish habitat and degrade downstream water quality. Reduction in crop yield on depositional site is often due to crop burial, runon of pesticides and inundation leading to anaerobiosis (Fahnestock *et al.,* 1995). 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. The economic result of downstream erosion is a rise in the cost of energy, water, food and goods formerly transported by river (Ritter, 2012).

2.3 Tillage

2.3.1 Definition and purposes

There are several definitions of tillage. According to Lal (1983), it is defined as physical, chemical or biological soil manipulation to optimize conditions for germination, seedling establishment and crop growth. Ahn and Hintze (1990) however, defined it as any physical loosening of the soil carried out in a range of cultivation operations, either by hand or mechanized. Tillage is the mechanical manipulations of soil to make it favourable for plant growth eliminating weeds during the growth of the plant (Sahay, 2008).

The fundamental purposes of tillage include: preparing suitable seed bed for plant growth, destroying competitive weed and, improving the physical condition of the soil. According to IBSRAM (1990), the overall goal of tillage is to increase crop production whilst conserving resources (soil and water) and protecting the environment. According to FAO (1993), the main functions and / or reasons farmers would invest time and labour in tillage operations are to produce optimal conditions for seed germination and emergence; control weeds in order to eliminate competition with crops for water and nutrients.

2.3.2 Types of tillage

Generally, tillage systems are classified into two, and these are: conservation tillage and conventional tillage (Mohammed and Umogbai, 2014).

2.3.2.1 Conservational tillage

Reduced soil compaction, economically viable crop rotations and establishment of surface residue cover are three core components of conservation agriculture (Kienzler *et al.*, 2012) which maintain the security of long-term crop productivity and decrease environmental risks (Valbuena *et al.*, 2012). Conservation tillage is now practised on approximately 125 million hectares which is about 9% of global arable lands (Kassam *et al.*, 2012). The conservation agriculture system was evaluated and adopted in different climatic regions of the world, such as in the tropical, sub-tropical and temperate regions over several decades. Conservation tillage leaves a minimum of 30% of crop residue on the soil surface or at least 1,100 kg/ha of small grain residue (Mohammed and Umogbai, 2014).

There are many variations of conservation tillage systems covering a broad spectrum of farming methods primarily aimed at reducing soil disturbance, conserving and managing crop residue to reduce erosion. Fundamentally, this is a form of mulching. Series of crops are planted into the residue, and the new crops eventually provide the vegetative protective cover. Especially in North America these techniques have become popular over recent decades (Uri, 1998).

Various methods are employed in conservation tillage practices. These include no-tillage, ridge tillage, mulch tillage or strip tillage.

2.3.2.1.1 Zero tillage

The no-till system is a specialized type of conservation tillage consisting of a one-pass planting and fertilizer operation in which the soil and the surface residues are minimally disturbed (Parr *et al*., 1990). The surface residues of such a system are of critical importance for soil and water conservation. Weed control is generally achieved with herbicides or in some cases with crop rotation. According to Lal (1983), no-tillage systems eliminate all pre-planting mechanical seedbed preparations except for the opening of a narrow (2-3 cm wide) strip or small hole in the ground for seed placement to ensure adequate seed/soil contact. The entire soil surface is covered by crop residue mulch or killed sod.

2.3.2.1.2 Ridge tillage

Ridge-till is a reduced disturbance planting system in which crops are planted and grown on ridges formed during the previous growing season and by shallow, in-season cultivation equipment (Mitchell *et al.,* 2006). Ridge tillage is a specific form of no-tillage wherein a new crop is planted on preformed ridges or hills or bunds from those of previous crop. After harvesting, the crop residues are left until planting time. The seeds are sown along the ridges. Sticks or other farm tools are used to make the openings for seeds (Christian and Ball, 1994).

2.3.2.1.3 Zone or strip tillage

Zone or strip tillage refers to any system in which a seedbed strip is established through a cover crop or crop residue, while still leaving a wide, untilled inter-row area (Lal, 1983). Strip tillage offers a potential solution to the challenges associated with both conventional tillage and no-tillage systems by improving the seedbed environment in poorly drained soils due to increases in soil moisture evaporation and soil temperature (Al-Kaisi and Hanna, 2002). Zone tillage appears to be one of the key technologies that make killed mulch and living mulch systems work. In some instances, the tilled zone may need to be fairly wide. It typically needs to be managed with additional cultivation, hoeing, or traditional mulching during the cropping season (Lal, 1983).

2.3.2.1.4 Mulch tillage

This refers to any system that ensures a maximum retention of crop residues (30% or more) on the soil surface. The soil is prepared in such a way that plant residues or other mulch materials are specifically left on or near the surface of the farm (Christian and Ball, 1994).

It is usually accomplished by substituting chisel ploughs, sweep cultivators, or disk harrows for the mouldboard plough or disk plough in primary tillage. This change in implements is attractive because residues are not buried deep in the soil, and good aerobic decomposition is thus encouraged. Weed control is accomplished with herbicides and/or cultivation (Aina *et al*., 1991).

2.3.2.1.5 Other tillage systems

Tillage systems that leave less than 30 % crop residues after planting are not classified as conservation tillage. However, these systems may meet erosion control goals with or without other supporting conservation practices such as strip cropping, contouring, terracing, etc.

Minimum tillage

In minimum tillage the seed is dropped in a narrow, shallow (~5cm deep) fissure produced by drawing a thin blade (tine), chisel or coulter through the uppermost soil layer. With either system the developing seedlings consequently grow through the stubble and unincorporated residues of the previous crop, unless these have previously been burnt or removed (Christian and Ball, 1994). Reduced tillage systems leave between 15 and 30% residue cover on the soil or 560 to 1100 kg/ha of small grain residue during the critical erosion period. This may involve the use of a chisel plough, field cultivators, or other implements (Mohammed and Umogbai, 2014).

Tillage rotation

Similar to crop rotation, tillage rotation indicates the use of rotation of different tillage systems. For residue management, rotating tillage systems to coincide with crop rotations is an option. For example, a no-tillage system following soybeans and a chisel or disk system following corn, can provide adequate erosion control after soybeans and allows for some tillage in the less fragile and more abundant corn residue. Rotating tillage systems, however, slows the development of improved soil structure and may require investment in more equipment (Aina *et al.*, 1991).

2.3.2.2 Conventional tillage

Conventional tillage involves the mechanical soil manipulation of an entire field by ploughing followed by one or more harrowing. The degree of soil disturbance depends on the type of implement used, the number of passes, soil and intended crop type (FAO, 2001). During the operation, the soils are cut, inverted and pulverized, burying most of the residues underneath (Luchsinger, 1979). The practice frequently causes soil compaction, affects soil physical properties, enhances biological degradation and results in declined crop yields. With pulverized soil on the surface and compaction below, a lot of soil is washed away with the first rains (Kaihura *et al.*, 1998). In the short-term, conventional tillage reduces runoff and soil compaction, but this effect is lost as soon as the first rainfall occurs producing a crusting effect (Rao *et al.*, 1998).

2.3.2.1 Intensive tillage systems

This system leaves less than 15% crop residue cover or less than 560 kg/ha of small grain residues on the soil. It often involves multiple operations with implements such as a mouldboard, disk and/ or chisel plough (Mohammed and Umogbai, 2014). This type of tillage system is often referred to as conventional tillage but as reduced and conservation tillage systems have been more widely adopted, it is often not appropriate to refer to this type of system as conventional (Aina *et al*., 1991).

2.3.2.2 Traditional tillage

Farmers in the tropics employ several traditional methods of seedbed preparation. Traditionally, weeds and bush regrowth are slashed manually and left on the soil as mulch or are burnt or allowed to decompose (Quansah and Oduro, 2004). Morgan, (1995) reported that in the humid and sub-humid regions of West Africa, and in some parts of South America, traditional tillage is practised mostly by manual labour, using native tools which are generally few and simple, the most important being the cutlass and hoe which come in many designs depending on function.

2.3.3 Short and long-term effects of soil tillage

The short-term effect of tillage has been reported by many researchers. Yield increases of 20 – 50% were reported for such crops as millet, sorghum or maize in West Africa (Pieri, 1989). This can be attributed mainly to the deeper loosening of the soil (15-20 cm instead of 5-10 cm by hand hoeing), which allows for increased water storage and exploitation of a greater soil volume by the plant roots (CTIC, 2002). However, with time undesirable long-term effects are observed like the formation of surface crust and the compaction of the subsoil (Kurt, 2002).

2.3.3.1 Effect of tillage on soil physical properties

Soil tillage is one of the fundamental agro-technical operations in agriculture because of its influence on soil properties, environment, and crop production (Kishor, 2013). Among the crop production factors, tillage contributes up to 20% (Hammel, 1989). To ensure normal plant growth, the soil must be prepared in such conditions that roots can have enough air, water and nutrients. Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel, 1989). Therefore Wang *et al.,* 2007 reported that conventional soil management practices result in losses of soil, water and nutrients in the field, and degrade the soil with low organic matter content and a fragile physical structure, which in turn lead to low crop yields and low water and fertilizer use efficiency.

2.3.3.1. 1 Bulk density

Bulk density is nearly always altered by tillage operations. An ideal soil contains about 50% solid particles and 50% pore space by volume. The magnitude of bulk density for agricultural soils commonly varies from 0.9 to 1.8 Mg m^{-3}(Erbach, 1987). The bulk density of a typical mineral soil is about 1.3 Mg m^{-3} (Singh *et al*., 1992). Bulk density is inversely related to the total porosity, which provides a measure of the porous space left in the soil for air and water movement.

Husnjak *et al. (*2002) reported that among the soil physical properties, strong reciprocal dependence was found between crop yield and soil bulk density, and strong direct dependence between crop yield and total porosity. Bhattacharya *et al. (*2008) reported that zero tillage increases the bulk density of soil. Anazodo and Onwuala (1984) also found that no-tillage system exhibits significantly higher bulk density, higher soil resistance to penetrometer pressure and lower porosity than plough-tillage and other tillage methods. The plough tillage system decreases soil bulk density (Olaniyan, 1990). Osuji and Babalola (1982) reported that bulk density increased more with time on plough-tillage and no-tillage systems.

2.3.3.1.2 Porosity and aeration

Tillage affects the soil total porosity as well as pore size distribution. Tillage increases the macro-porosity while compaction increases micro-porosity. Conservation tillage systems result in more continuous pore systems (Bhattachariya *et al.*, 2008), while minimum and no tillage decrease the soil porosity for aeration, but increase the capillary porosity and as a result, enhance the water capacity of soil along with poor aeration of soil (Wang and Wen, 1994)**.** A limiting oxygen supply will also restrict the development of the root system even in uncompacted soil and minimal tillage could increase the quantity of porosity (Allen and Fenster, 1997).

2.3.3.1.3 Infiltration rate

One important function of soil is transmission of water, which directly affects plant productivity and the environment. Infiltration of water increases water storage for plants and groundwater recharge and reduces erosion. Conversion from conventional tillage to zero tillage usually increases available water capacity and infiltration rate (McGarry *et al.,* 2000; Bhattacharya *et al.,* 2008) and decreases runoff (Wright *et al.,* 1999). It has been reported that untilled compared to tilled soil had greater and lower infiltration rates (McGarry *et al.*, 2000).

2.3.3.2 Effect of tillage on soil chemical properties

In the semi-deciduous forest zone of Ghana, Quansah and Ampontuah (1999) reported the effect of tillage on fertility erosion. Their study showed hand tillage and all tillage in exception of plough-plant to cause significant losses of N, P, K and organic matter. In all cases, excessive tillage recorded the highest losses of nutrients while plough-plant had the least (Quansah and Ampontuah, 1999).

A good tillage practice can alleviate soil related constraints while a poor tillage may lead to a range of degradation processes, such as deterioration in soil structure, depletion of soil organic matter and fertility and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1995). A good tillage practice can also lead to better spatial distribution of roots, improving the nutrient and water uptakes, hence improved productivity (Singh and Malhi, 2006).

Thomas *et al.* (2007) investigated changes in plant nutrients and pH with different tillage measures. According to them, conventional tillage does not only result in soil loss but also degrades the soil carbon in a long monoculture. At the depth of 0-20 cm, soil organic carbon loss increased with conventional tillage (Zinn *et al.,* 2005). Halvorson *et al.* (2001) found that the interactive effects of different tillage systems such as no tillage, conservation tillage, or minimum tillage and N rate on grain N uptake was significant in increasing N removal with increasing N rate. Zibilske and Bradford (2003) indicated that the chemical nature of soil P is also affected by tillage practice, with P solubility being increased under conservation tillage.

2.4 Effect of tillage on runoff and soil loss

Soil erosion and accompanying sedimentation in the downstream areas are continues to be a threat to the world's land and water resources. It is a major environmental problem world-wide (Elsen, 2003). Soil loss is one of the causes of soil infertility and productivity deterioration. Soil removed by erosion, carries nutrient, pesticides and other harmful agrochemicals into rivers, streams, and ground water resources. Under natural vegetation cover, soil erosion is non-existent or minimal. With the removal of vegetation cover and cultivation for two or more seasons, the inherent fertility drastically reduces and erosion is accelerated (Pandey, 2007).

Tillage induced soil erosion is significant and contributes to the soil degradation process, occurring in much of the hilly upland areas of the humid tropics (Thapa, 2001). Ridge tillage system reduces the downslope transport of soil on sloping field, but weed control for this system under a humid tropical environment is challenging (Thapa, 2001). An important component of the technology is the partial shallow incorporation and rolling of plant residues after harvest. Organic plant residues (mulch) left on soil surface have a fundamental role in the protection against soil erosion (Lal *et al.,* 2007).

Conservation tillage is increasingly applied as a conservation agriculture measure to reduce soil loss by water erosion in regions of intense agricultural activity, representing 95 million hectares globally (Lal *et al.,* 2007). In conservation tillage systems, crop residues from a previous harvest are left in place as a soil surface cover or are slightly incorporated into the topsoil. Both practices are known to reduce soil loss by runoff flow erosion (Gim´enez and Govers, 2007). Madarasz (2011) reported that in conservation tillage practice, runoff was reduced and soil erosion decreased. Chow *et al.* (2000) found higher runoff and soil losses under mouldboard plough relative to other conservation tillage practices on both 8 and 11% slopes. Beare *et al.* (1994) found that in conventional tillage fields, macro aggregates (>250 um) were fewer and less stable than those from no-tillage and as a result, soil and soil organic matter (SOM) were easily lost through runoff. Roy and Nabhan (2000) also reported that water stable aggregates were higher in conservation tillage practices such as no-tillage and chisel ploughing that disturb the soil less than conventional tillage. Norwood (1994) found 62% more water in the 0 - 0.9 m depths in no-tillage due to less evaporation and no surface runoff compared to conventional tillage. Vogel (1992) observed that conventional tillage lost more soil than conservation tillage practices.

2.5 Effect of tillage on soil moisture conservation

The water in the unsaturated zone of the soil is called soil moisture. Although soil moisture corresponds to 0.005% of water on the Earth, it plays an important role in the water cycle (Tran, 2010). Soil moisture is an important factor that influences seed germination, emergence and plant growth. Precise knowledge of the surface moisture is also important for the reconstruction of precipitation fields, evaporation, and infiltration to improve the prediction of runoff (Kerr and Cabot, 2009).

Soil structure and moisture removal changes are dependent on soil properties, types of tillage and climatic conditions. Moisture removal patterns are of utmost importance to semi-arid regions since moisture is usually the limiting crop yield factor (Lindwall, 1984). Tillage also exerts adverse effects on soil when it is performed under inadequate moisture conditions, or when inadequate tillage implements are used. However, other studies have shown that tillage is one of the most essential operations carried out to improve soil structure, increase infiltration capacity and aeration (Lio, 2006). Soil water content is affected by tillage because of changes produced in surface runoff, and evaporation (Zhai *et al.,* 1990).

The increase in soil water storage under conservation tillage can be attributed to reduced evaporation, greater infiltration, and soil protection from rainfall impact (Sarauskis *et al.,* 2009). The adoption of no-tillage allows more intensive cropping sequences (Halvorson *et al.,* 2000), because no-tillage results in increased rainwater infiltration and retains more water in the potential root compared to conventional-till. According to Farhani *et al.* (1998) no-tillage conserved more surface residue, resulting in less evaporation loss. The result is that crops use soil water more efficiently under no-tillage (Peterson *et al.,* 2001) and by this the growing period is increased (Farhani *et al.,* 1998). Farhani *et al.* (1998) concluded that no-tillage practices resulted in improved soil conditions such as improved soil moisture content, less fluctuation in soil temperature and reduced soil erosion.

2.6 Effect of tillage on crop yield

Tillage practice suppresses weeds, controls soil erosion and maintains adequate soil moisture. Tillage creates an ideal seedbed condition for seedling emergence and development (Licht and Kaisi, 2005). Tillage practices affected plant root growth (Lampurlanes *et al.,* 2001), grain yield and the incomes of farmers (Cavalaris and Gemtos, 2004). Motavalli *et al.* (2003) noted that deep tillage improved the root length, root proliferation and nitrogen recovery efficiency (NRE), i.e. Lower NRE was recorded in no tilled soil treatment than the compacted in sub-soiling treatments. Khattak *et al.* (2004) suggest that 15% more grain yield in deep tilled plot (using mould board plough). Inappropriate tillage practices may reduce crop growth and yield whereas selection of an appropriate tillage practice for crop production is very important for optimum growth and yield. Conversely, with optimum management, crop yields can be 20 to 30% greater for no-tillage than the best tilled production systems on these same soils (Wright *et al.*, 2008). Lawrence *et al.* (1994) made similar observation that conservation tillage practices resulted in higher yields than conventional tillage (CT) in a four year study in a semi-arid environment in Australia. Eckert (1994) reported that no-tillage yielded more in drier years whereas mouldboard ploughing yielded more in wetter years in a moderately well drained soil. However, Munyati (1994) found out that the cumulative total yields in a five-year study were higher in conventional tillage than in conservation tillage practices. Hussein *et al.* (1999) found lower yields in no-tillage in the first year, but no-tillage later yielded more than conventional tillage in the last five years of the experiment. In contrast, Kapustan *et al.* (1996) reported no differences in maize yields between no-tillage and conventional tillage over time. Use of correct tillage methods may contribute to higher profits, crop yields, soil improvement and protection (Hanna and Al-kaisi, 2009).

2.7 Mineral and organic fertilizers use in crop production

Soil fertility maintenance is essential in achieving and maintaining high crop yields over a period of time. Fertilizer application has usually been the major means of supplying plant nutrients (Ismail *et al.*, 1996). Lombin *et al.*, 1992 suggest that organic and inorganic fertilizers applied to the soil supply plant nutrients for crop growth and affect the plant's physiological processes. Application of manure has been reported to over time, reduce soil degradation, bulk density and increase soil water retention and hydraulic conductivity (Droogers and Bouma, 1996). Complementary application of organic and inorganic fertilizers enhances nutrient synchrony and reduces losses by converting inorganic nitrogen into organic forms (Kramer *et al.,* 2002). It is also important not only for enhancing the efficiency of the fertilizers, but also in reducing environmental problems that may arise from their use (Bayu *et al.,* 2006). Several field researches reported that integrated nutrient management is the best approach to restore/ maintain soil fertility and productivity on sustainable basis (Khan *et al.*, 2008).

2.7.1 Effect of mineral and organic fertilizers on soil properties

The inherent poor fertility of tropical soils has made nutrients availability in them to be largely controlled by organic matter (Linger and Critchley, 2007). Mbagwu *et al*. (1994) reported that organic manures improved physical properties of soils; with poultry droppings enhancing soil fertility (Ajayi *et al.,* 2003). Poultry droppings increased soil hydraulic conductivity and reduced bulk density thereby improving water infiltration and aeration necessary for optimum performance of crops (Agele, 2000). Poultry manure is a source of organic manure that enriches the soil; it does not only increase the nutrient status of the soil but improves the structure too (Odiete and Ogunmoye, 2005). Poultry manure may have higher values for P and K (Harty *et al.,* 1992) but should be managed for its N value (Uyovbisere *et al.,* 2000). About 70% of N in poultry manure can be available to the crop during the first year of application (Zublena *et al.,* 1997). NPK fertilizer application sustains soil fertility and crop production and poultry manure when combined with mineral fertilizer can exhibit long residual effect (Uyovbisere *et al.*, 2000). Soil pH, organic carbon, total N and available P were significantly enhanced by poultry manure application and the combined application in the first year (Isitekhale and Osemwota, 2010).

Organic matter increases soil fertility and productivity by improving the soil water and nutrients holding capacity, lowering the soil pH, improving the soil cation exchange capacity and ensuring the sustainability and availability of nutrients (Deksissa *et al.*, 2008). Many researchers have found that conventional tillage operations disturbs soils and generally increases residue decomposition, organic N mineralization, and the availability of N for plant use.

2.7.2 Effect of mineral and organic fertilizers on crop yield

Beside appropriate selection of tillage operations, the improvement in average yield per hectare can be obtained if soil fertility is maintained through proper dose, application method and use of organic and inorganic fertilizers (Lombin *et al.*, 1991). In many countries in the world, balanced use of organic manure and inorganic fertilizers has been considered as one of the best and comprehensive soil fertility management strategies (Lombin *et al.*, 1991). In several studies, high and sustainable crop yields are only possible with combined use of inorganic fertilizers with organic manure (Raman *et al*, 1996; Singh *et al.*, 1999). Some other studies also have recommended judicious and balanced NPK fertilization combined with organic matter amendments for high and sustained crop yields (Makinde *et al.*, 2001). The high yields are attributed to complementary application of organic and inorganic fertilizers as they increase nutrient accessibility and reduce losses by converting inorganic nitrogen into organic forms (Kramer *et al.,* 2002).

Plant residues with high C/N ratios and high lignin contents decomposed and released nutrients slowly (Tian *et al.*, 1992) while poultry manure could be a better alternative as it decomposes easily and makes nutrients available to plants. Poultry manure treatments along lower levels of NPK produced higher values for plant height, leaf area index and biomass and grain yield of corn (Boateng *et al.*, 2006).

2.8. Soil Characteristics

According to Lujan (2003) many aspects of soil behaviour in the field such as hydraulic conductivity, water retention, soil crusting, soil compaction, and workability are influenced strongly by the primary particles. Lixisols comprise soils that have higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Lixisols have a high base saturation and low-activity clays at certain depths. Many Lixisols are surmised to be polygenetic soils with characteristics formed under a more humid climate in the past. Degraded surface soils have low aggregate stability and are prone to slaking and/or erosion where exposed to the direct impact of raindrops. Tillage of wet soil or use of excessively heavy machinery compacts the soil and causes serious structure deterioration (IUSS Working Group, 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of study area

The experiment was carried out at the KNUST Faculty of Agriculture Research Station located at Anwomaso, Kumasi. The mid-point of experimental plot is approximately latitude 1° 31' 32.88" W and longitude 6° 41' 51.24" N.

3.2 Climate and vegetation

The area falls within the moist semi-deciduous forest belt of Ghana with a double maxima rainfall separated by a short dry spell in August. The main annual rainfall is 1400 mm, with March, April, May, June and July constituting the major rainy season. The minor wet season is from September to November with a maximum rainfall in October. The main dry season is from December to February. Temperatures are typically high throughout the year with a monthly mean of 26º C. Mean absolute highest and lowest temperatures are recorded in February and August respectively. Variations between day and night temperatures are greater during the dry season than during the wet seasons. Morning relative humidity is usually highest during the wet season from June to October (Dickson and Benneh, 1988).

3.3 Soil

The soil at the experimental site belongs to the Kotei Series (Ghana classification) and classified according to the world reference base of soil resources as Plinthic Vertic Lixisol (Profondic, Chromic). The average slope was 6% (IUSS Working Group, 2006) The soil is characterized by a layer of dark brown sandy loam with moderate fine granular structure and contains many very fine roots. Underlying the A horizon is about 25-37 cm of brown sandy clay loam with a moderate medium subangular blocky structure. The soil pH was 5.2.

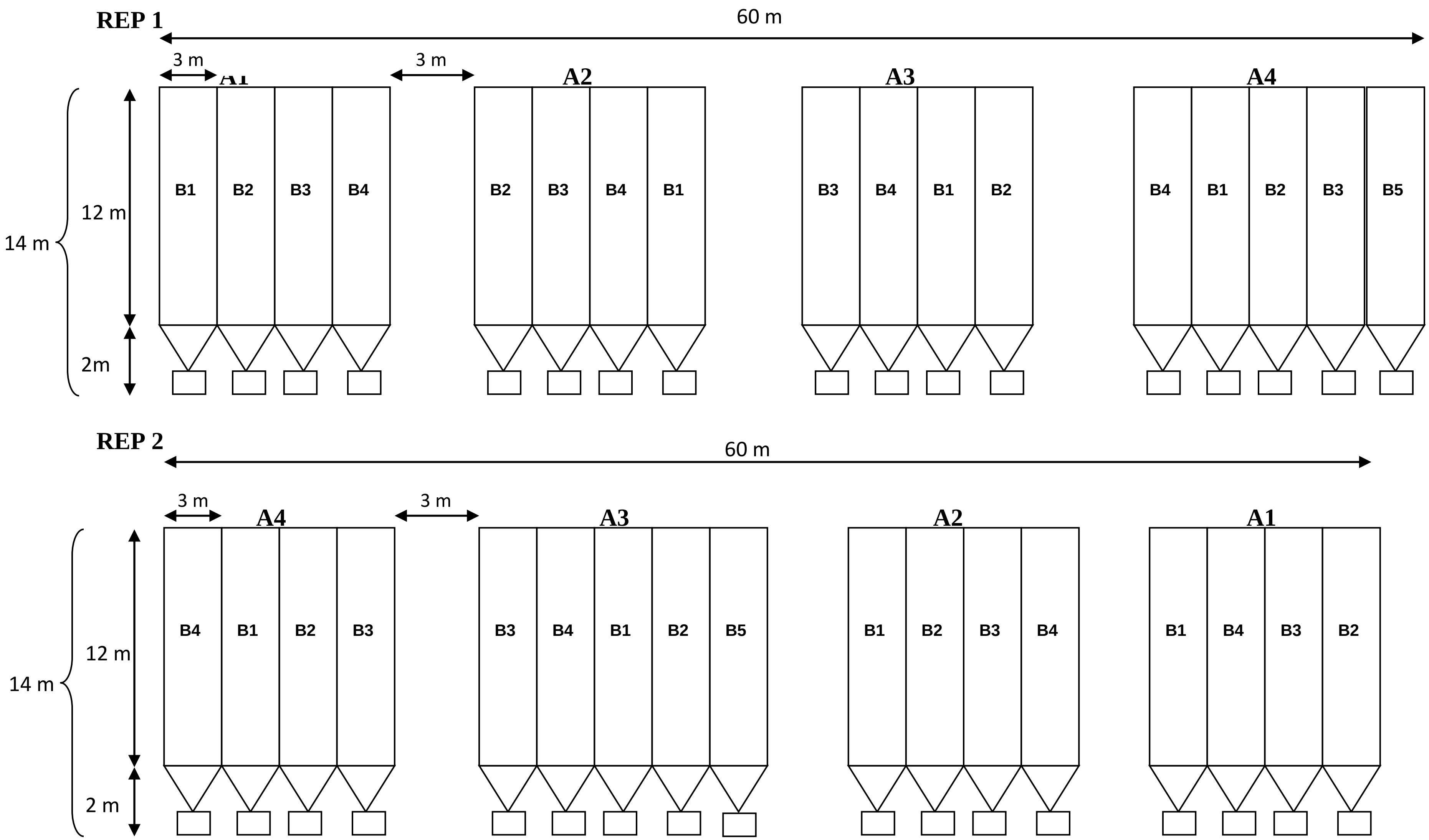
3.4 Experimental design/ treatments

The experiment was a split-plot arranged in Randomized Complete Block Design (RCBD) with 3 replications. The main plot factor consisted of no-tillage (A1), plough-plant (A2), plough-harrow-plant (A3), hoe-tillage (A4) and the bare plots (B5) whilst the subplot factor comprised soil fertility amendments (Table 3.1).

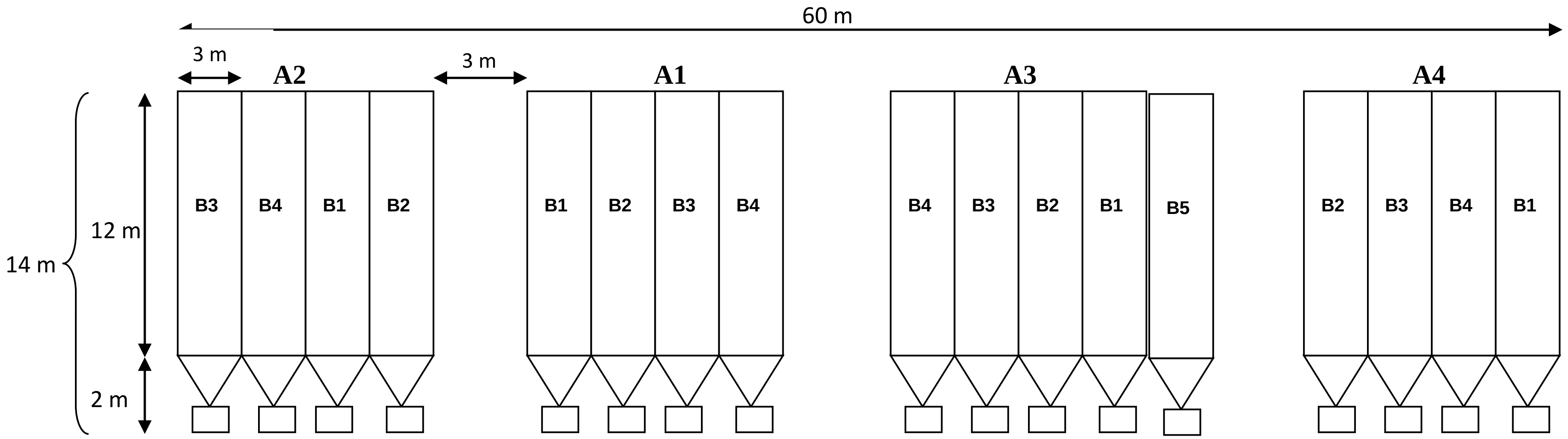
There were a total of 12 main plots and 51 sub-plots (Figure 3.1). The experiment was carried out within two seasons (major and minor rainy seasons). The same plot for each treatment was used during the two seasons of experimentation.

Table 3.1: Soil fertility amendment

Soil fertility amendments (sub-plot)	**Rate of application**
Control (B1)	No NPK and No Poultry Manure (PM)
100% NPK fertilizer (15-15-15) + N (B2)	90-60-60 kgN-P_2O_5-K_2O/ha
Poultry Manure (PM) (B3)	3 t PM/ha
½ Rate of PM/ha + ½ Rate of NPK Fertilizer + ½ Rate N (Urea) (B4)	45-30-30 kg N-P_2O_5-K_2O/ha + 1.5 t PM/ha


REP 1
60 m
3 m
3 m
A1
A2
A3
A4
14 m
12 m
2m
B1 B2 B3 B4
B2 B3 B4 B1
B3 B4 B1 B2
B4 B1 B2 B3 B5
REP 2
60 m
3 m
3 m
A4
A3
A2
A1
14 m
12 m
2 m
B4 B1 B2 B3
B3 B4 B1 B2 B5
B1 B2 B3 B4
B1 B4 B3 B2

REP 3



Total land area = 60 m × 14 m × 3 = **2520 m^2**

B5: Bare plot

Figure 3.1: Runoff plot layout

3.5 Runoff plot studies

3.5.1 Design of runoff plots

To study the response of maize grain yield to different soil amendments and tillage, fifty one runoff plots were established. The experimental trial consisted of three blocks each containing 16 plots and a bare plot. Each plot measured 12 m in length and 3 m in width and 3 m alley between each main plot. The area per plot was 36 m2. The plot was arranged on the slope with their longer axes along the slope. Each plot was separated from the other by aluzinc sheets split into narrow strips and driven 15 cm into the soil leaving 15 cm above the soil surface. At the lower ends of each plot, there was measuring equipment for determining the amount of runoff and soil loss from each storm. These consisted of collecting troughs, tipping buckets and 20 litre plastic containers.

3.5.2 Collecting trough

The collecting trough was made of aluzinc sheets with the wider edge measuring 211 cm and a width of 32 cm. The wider edge was set at level with the soil surface at the lower ends of the runoff plots to ensure that the eroded materials settled on it. At the exit end of the trough, there was a wire screen covering of 1.25 cm mesh to retain the large fragments of organic matter and soil particles from the runoff water before passing into the tipping bucket device through a covered rectangular channel.

3.5.3 Tipping bucket and the runoff sampling devices

Runoff was measured in this study with the aid of tipping buckets. The functional principle of the tipping bucket device is to count how often the two buckets with known volume are filled with runoff and self-emptied. The runoff is always collected at every point in time into one bucket of the tipping bucket device. The total runoff rates was determined by recording the number of tips recorded by a mechanical counter fitted to the side of the tipping bucket device and the volume of runoff in the 20 L container a rubber tubing connected below the narrow exit end of the collecting trough.

3.5.4 Drainage

The drainage system consisted of four rectangular concrete trenches each of which was 1.83 m wide, 12.19 m long and 1.52 m deep. These trenches have been designed to slope and open into each other through PVC pipes. The last trench, into which all the water from the other three was collected, opened into a concrete drain which led the water out of the field.

3.6 Fertilizer and poultry manure application

The amendments (poultry manure, NPK fertilizer and poultry manure + NPK fertilizer) were applied to their respective treatment plots two weeks after planting (WAP). However, the control plots did not receive any amendment. At five WAP, plots amended with poultry manure + NPK fertilizer, and NPK fertilizers were top dressed with N in the form of urea.

3.7 Agronomic practices

Obatanpa maize variety, which is a 110 days maturing variety, was planted in rows at a spacing of 80 cm x 40 cm (80 cm between rows and 40 cm along the rows) as commonly used in most experimental stations and commercial farms in Ghana. Planting was carried out the same day for all treatments. Three seeds were planted per hill and seedlings later thinned to two per hill one week after germination. Obaatanpa was selected because it has been widely adopted by farmers and consumers in Ghana.

3.8 Collection of data

3.8.1 Runoff volume

After each rain, the volume of runoff in each sampling gallon attached to the collecting troughs was measured directly using calibrated plastic buckets. However, since a portion of the collecting trough was exposed to direct rainfall, its percentage contribution to runoff was calculated and subtracted from the total runoff measured from the sampling gallons.

Total runoff per plot was determined as the sum of the total runoff measured from tipping buckets and that in the sampling gallons.

Runoff was expressed as:

$$\text{Runoff (mm)} = \frac{\text{Total runoff volume (m}^3\text{)}}{\text{Area of plot (m}^2\text{)}} \times 1000 \qquad \textit{Equation 1}$$

3.8.2 Direct weighing of soil loss

The eroded sediment that collected on the trough was scrapped and weighed using a Salter Balance. When wet soil was weighed, a sample of 20 g was oven dried at 105 ^{o}C for 24 hours and the total dry weight of the eroded sediment was calculated. Total soil loss per plot was the sum of the total solids in the runoff and that on the trough.

3.8.3 Crop growth rate

Five plants were randomly selected from the middle rows of each sub-plot and tagged for only growth rate observation. The tagged plants were used for fortnightly plant height measurements up to the end of tasseling. Height measurements were made from ground level to the last flag leaf of the tagged plants using a graduated rod.

3.8.4 Crop yield

Crop yield was measured at 4 months after planting. Plants from the middle rows of each sub-plot were harvested from 3.84 m^2 (net plot area) and their ears weighed. After shelling, the cobs were weighed and dried in an oven for 48 hours at 70 ^oC. The grains were threshed, weighed and expressed in Mg / ha.

3.9 Soil physical analysis

3.9.1 Determination of soil bulk density

Bulk density was measured by the core method (Blake and Hartge, 1986). Bulk density is a measure of the weight of the soil per unit volume expressed in g cm^{-3} or Mg m^{-3} (usually given on an oven-dry (105 ^OC) basis). A core sampler was driven into the soil with the aid of a mallet.

The core sampler with its content was then dried in the oven at 105^O C to a constant weight. The volume of the core sampler was determined by measuring height and radius of the core sampler.

Calculation:

$$\text{Dry bulk density } \rho_b \text{ (Mg m}^{-3}\text{)} = \frac{W_2 - W_1}{V} \qquad \textit{Equation 2}$$

where:

ρ_b = dry bulk density

W_2 = Weight of core cylinder + oven – dried soil

W_1 = Weight of empty core cylinder

V = Volume of core cylinder ($\pi r^2 h$), where:

$\pi = 3.142$

r = radius of the core cylinder

h = height of the core cylinder

3.9.2 Gravimetric moisture content (%)

This is based on the principle that moisture content in field soil sample is determined by oven-drying a previously weighed sample at 105 ^{O}C till it attains a constant weight usually after 24 hours. In this method, the loss in weight after oven-drying at 105 ^{O}C for 24 hours expressed as a fraction of the oven-dried soil represents the moisture content. A moisture can with lid was oven–dried at 105 ^{O}C to a constant weight and the weight recorded (W_1). Ten grammes of soil were weighed into a moisture can and the weight recorded. The can with the soil and the lid were oven-dried at 105 ^{O}C for 24 hours to a constant weight (W_3).

Calculation:

$$\%\,\theta m = (Mw/Ms) \times 100 \qquad \textit{Equation 3}$$

where:

Mw = weight of water

Ms= weight of dry soil

3.9.3 Volumetric moisture content

This was calculated by multiplying the gravimetric moisture content by the bulk density.

$$\theta v = \theta m \times (\rho_{b} / \rho w) \qquad \textit{Equation 4}$$

where:

θm = gravimetric moisture content

ρ_b = dry bulk density

ρw = density of water

3.9.4 Soil moisture storage

The soil moisture storage was computed for each treatment at the depths of 0 -10 cm, 10- 20 cm and 20-30 cm.

$\theta h = \theta v \text{ x } z$ *Equation 5*

where:

θh = depth of water stored (mm)

θv = volumetric water content

Z = depth of soil in mm

3.9.5 Total porosity and aeration porosity

The total porosity was calculated by the relationship between bulk density and particle density as follows:

$f = \left(1 - \frac{Pb}{Ps}\right) x100$ *Equation 6*

$\Sigma q = (f - \theta v) \text{ x}100$ *Equation 7*

where:

f = total porosity

P_s = particle density, with a value of 2.65 g/cm^3

Σ_a = aeration porosity

3.9.6 Soil depth reduction due to soil loss

The physical loss of soil through erosion reduces the depth of soil needed for the storage of water and nutrient and, root room for root growth. It is expressed as:

$$\rho b = \frac{Ms}{vt} = \frac{Ms}{A \times h} \qquad \textit{Equation 8}$$

$$h = \frac{Ms}{A \times \rho b} \qquad \textit{Equation 9}$$

where:

h = depth reduction due to soil loss (m)

Ms = weight of dry soil loss (Mg)

vt = total volume of soil loss (m^3)

A = area from which soil is lost (m^2)

ρ_b = bulk density of parent soil from which eroded soil originates (Mg m^{-3}).

3.10 Soil sampling, preparation and analysis

Soil samples were taken from each plot before fertilizer application and at harvest and analysed for nutrient status. The parameters determined were soil pH, organic carbon, total nitrogen, available phosphorus, and exchangeable potassium.

3.10.1 Soil pH

The pH of the soil was determined using a Suntex pH (mv) Sp meter (701) for soil: water ratio of 1:2.5 as described by McLean (1982). A 20 g soil sample was weighed into a 100 mL beaker. To this 50 mL distilled water was added and the suspension was stirred continuously for 20 minutes and allowed to stand for 15 minutes. After calibrating the pH meter with buffer solutions of pH 4.0 and 7.0, the pH was read by immersing the electrode into the upper part of the suspension.

3.10.2 Soil organic carbon

Organic carbon was determined by a modified Walkley-Black wet oxidation method (Nelson and Sommers, 1982). Two grammes of soil sample were weighed into 500 mL erlenmeyer flask. A blank sample was also included. Ten millilitres of 1.0 N $K_2Cr_2O_7$ solution was added to the soil and the blank fl;p ask. To this, 20 mL of concentrated sulphuric acid was added and the mixture allowed to stand for 30 minutes on an asbestos sheet. Distilled water (200 mL) and 10 mL of concentrated orthophosphoric acid were added and allowed to cool. The excess dichromate ion ($Cr_2O_7^{2-}$) in the mixture was back titrated with 1.0 M ferrous sulphate solution using diphenylamine as indicator until the colour changed from a blue-black colouration to a permanent greenish colour. A blank determination was carried out in a similar fashion in every batch of samples analysed without soil.

Calculation:

$$\%C = \frac{\mathrm{N} \times (\mathrm{V_{bl}} - \mathrm{V_s}) \times 0.003 \times 1 \cdot 33 \times 100}{\mathrm{Weight\ of\ soil\,(g)}}$$

Equation 10

where:

N =Normality of $FeSO_4$ solution

Vbl = mL of $FeSO_4$ used for blank titration

Vs = mL of $FeSO_4$ used for sample titration

0.003= milli-equivalent weight of C in grams (12÷4000)

1.33 = correction factor used to convert the Wet combustion C value to the true C value since the Wet combustion method is about 75 % efficient in estimating

C value (i.e. 100÷75 = 1.33).

3.10.3 Total nitrogen

The total nitrogen content of the soil was determined using the Kjeldahl digestion and distillation procedure as described by Bremner and Mulvaney (1982). Ten (10) grammes soil was weighed into a 500 mL Kjeldahl digestion flask and one spatula full of copper sulphate, sodium sulphate and selenium mixture followed by 30 mL of concentrated H_2SO_4 were added. The mixture was heated strongly to digest the soil to a permanent clear green colour. The digest was cooled and transferred to a 100 mL volumetric flask and made up to the mark with distilled water. A 10 mL aliquot of the digest was transferred into a Tecator distillation flask and 20 mL of 40 % NaOH solution was added. Steam from a Foss Tecator apparatus was allowed to flow into the flask. The ammonium distilled was collected into a 250 mL flask containing 15 mL of 4 % boric acid with mixed indicator of bromocresol green and methyl red. The distillate was titrated with 0.1 N HCl solution. A blank digestion, distillation and titration were carried out without soil as a check against traces of nitrogen in the reagents and water used (Okelabo *et al.,* 1993).

Calculation:

$$\% \mathrm{N} = \frac{(a-b) \times 1.4 \times \mathrm{N} \times \mathrm{V}}{s \times t}$$

Equation 11

where:

a = mL HCl used for sample titration

b = mL HCl used for blank titration

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

N = normality of HCl

V = total volume of digest

s = mass of air dry soil sample taken for digestion in grams (10.0 g)

t = volume of aliquot taken for distillation (10.0 mL)

3.10.4 Available phosphorus

This was determined using the Bray P1 method (Olsen and Sommers, 1982). The method is based on the production of a blue complex of molybdate and orthophosphate in an acid solution. A standard series of 0, 0.8, 1.6, 2.4, 3.2, and 4.0 μgP/mL were prepared by diluting appropriate volumes of the 10 μgP/mL standard sub-stock solutions. These standards were subjected to colour development and their respective transmittances read on a spectrophotometer at a wavelength of 520 nm. A standard curve was constructed using the readings.

A 2.0 g soil sample was weighed into a 50 mL shaking bottle and 20 mL of Bray-1 extracting solution was added. The sample was shaken for one minute and then filtered through No. 42 Whatman filter paper. Ten millilitres of the filtrate was pipetted into a 25 mL volumetric flask and 1 mL each of molybdate reagent and reducing agent were added for colour development. The percent transmission was measured at 520 nm wavelength on a spectrophotometer. The concentration of P in the extract was obtained by comparison of the results with a standard curve.

Calculations:

$$\mathrm{P\ (mg\ kg^{-1})} = \frac{\text{Graph reading} \times 20 \times 25}{\mathrm{w} \times 10}$$ *Equation 12*

where:

w = sample weight in grammes

20 = mL extracting solution

25 = mL final sample solution

10 = mL initial sample solution

3.10.5 Determination of exchangeable potassium

Potassium and sodium in the soil extract were determined by flame photometry. Standard solutions of 0, 2, 4, 6, 8 and 10 ppm K^+ and Na^+ were prepared by diluting appropriate volumes of 100 ppm K^+ and Na^+ solution to 100 mL in volumetric flask using distilled water. Photometer readings for the standard solutions were determined and a standard curve constructed. Potassium and sodium concentrations were read from the standard curve.

Calculations:

$$\text{Exchangeable } K^+ \text{ (cmol +/kg soil)} = \frac{\text{Graph reading} \times 100}{39.1 \times \mathrm{w} \times 10}$$ *Equation 13*

$$\text{Exchangeable } Na^+ \text{ (cmol +/kg soil)} = \frac{\text{Graph reading} \times 100}{23 \times \mathrm{w} \times 10}$$ *Equation 14*

where:

w = air-dried sample weight of soil in grams

39.1 = atomic weight of potassium

23 = atomic weight of sodium

10 = mL initial sample solution

3.10.6 Particle size analyses

The hydrometer method was used for this analysis. This method relies on the differential settling velocities of different particle sizes within a water column. The settling velocity is also a function of liquid temperature, viscosity and specific gravity of the falling particle (Okalebo *et al.*, 1993).

A 51 g soil sample was weighed into a 'milkshake' mix cup. To this 50.0 mL of 10% sodium hexametaphosphate (Calgon) along with 100 mL distilled water were added. The mixture was shaken for 15 minutes after which the suspension was transferred from the cup into a 1000 mL measuring cylinder and distilled water added to reach the 1000 mL mark. The mixture was inverted several times until all soil particles were in suspension. The cylinder was placed on a flat surface and the time noted. The first hydrometer and temperature readings were taken at 40 seconds. After the first readings the suspension was allowed to stand for 3 hours and the second hydrometer and temperature readings taken. The first reading indicates the percentage of sand and the second reading percentage clay. The percentage of silt was determined by the difference.

Calculations:

$$\%\,\text{Sand} = 100 - [\text{H1} + 0.2\,(\text{T1} - 20) - 2.0] \times 2 \qquad \textit{Equation 15}$$

$$\%\,\text{Clay} = [\text{H2} + 0.2\,(\text{T2} - 20) - 2.0] \times 2 \qquad \textit{Equation 16}$$

$$\%\,\text{Silt} = 100 - (\%\,\text{sand} + \text{clay}) \qquad \textit{Equation 17}$$

where:

H_1 = Hydrometer reading at 40 seconds

T_1 = Temperature at 40 seconds

H_2 = Hydrometer reading at 3 hours

T_2 = Temperature at 3 hours

0.2 (T – 20) = Temperature correction to be added to hydrometer reading

- 2.0 = Salt correction.

3.11 Poultry manure characterization

The poultry manure which was applied as a soil amendment was obtained from Ayigya farms. Before application, a representative sample was taken, dried in the oven at 40 °C (Anderson and Ingram, 1993) and ground to pass through a 1 mm sieve. Organic carbon, total nitrogen, phosphorus and potassium were determined and used to assess the quality of the manure.

3.11.1 Nitrogen

Total N was determined by the Kjeldahl method in which poultry manure was oxidized by sulphuric acid and hydrogen peroxide with selenium as catalyst. In the case of the poultry manure, 20 g oven-dried sample was ground in a stainless steel hammer mill and passed through a 1 mm sieve. A 0.5 g sample was digested in a 10 mL concentrated sulphuric acid with selenium mixture as catalyst. The resulting clear digest was transferred into a 100 mL conical flask and made to volume with distilled water. A 5 mL aliquot of the sample and a blank were pipetted into the Kjeldahl distillation apparatus separately and 10 mL of 40 % NaOH solution added followed by distillation. The evolved ammonia gas was trapped in a 25 mL of 2 % boric acid. The distillate was titrated with 0.1 M HCl with bromocresol green-methyl red as indicator (Soils Laboratory Staff, 1984).

Calculation:

% N/DM = $\dfrac{(a-b)\times M\times 1.4\times mcf}{w}$ *Equation 18*

where:

a = mL HCl used for sample titration

b = mL HCl used for blank titration

M = molarity of HCl

1.4 = 14 × 0.001 × 100 % (14 = atomic weight of N)

DM = dry matter

w = weight of sample

3.11.2 Organic carbon

Organic carbon content of the poultry manure was determined using the dichromate-acid oxidation method. Ten millilitres (10 mL) each of concentrated sulphuric acid, 0.5 N potassium dichromate solution and concentrated orthophosphoric acid were added to 0.05 g of sample in Erlenmeyer flask. The solution was allowed to stand for 30 minutes after addition of distilled water. It was then back titrated with 0.5 N ferrous sulphate solutions with diphenylamine indicator.

The organic carbon content was calculated from the equation:

% Carbon = $\dfrac{N\times(a-b)\times 3\times 10^{-3}\times 100\times 1.3}{w}$ *Equation 19*

where:

N = normality of ferrous sulphate

a = mL ferrous sulphate solution required for sample titration

b = mL ferrous sulphate solution required for blank titration

w = weight of oven- dried sample in gram

3 = equivalent weight of carbon

1.3 = compensation factor allowing for incomplete combustion

3.11.3 Phosphorus

A 5 mL aliquot of the filtrate was taken into a 25 mL volumetric flask. Five millilitres of ammonium vanadate solution and 2 mL stannous chloride solution were added. The volume was made up to 25 mL with distilled water and allowed to stand for 15 minutes for full colour development. A standard curve was developed concurrently with phosphorus concentrations ranging from 0, 5, 10, 15 to 20 mg P/kg organic material. The absorbance of the sample and standard solutions were read on a spectronic 21D spectrophotometer at a wavelength of 470 nm. The absorbance values of the standard solutions were plotted against their respective concentrations to obtain a standard curve from which phosphorus concentrations of the samples were determined.

3.11.4 Potassium

Potassium in the leachate was determined using a Gallenkamp flame analyzer. A standard solution of potassium was prepared with concentrations of 0, 20, 40, 60, 80 and 100 mg/litre of solution. The emission values which were read on the flame analyzer were plotted against their respective concentrations to obtain standard curves.

3.12 Added benefit

The method by Vanlauwe *et al.* (2001) was used to assess the added benefit (AB) of the interaction effect of tillage and soil amendments. The following general expression was used.

Added benefit (AB) = Y comb - (Y1–Y cont) – (Y2 –Y cont) –Y cont *Equation 20*

where:

AB = Added Benefits,

Y comb = mean of the interaction term.

Y 1= mean of the main effect of the first interaction

Y cont = mean of the main effect of the control

Y2 = mean of the main effect of second interaction term.

For runoff and soil loss, negative AB values are considered better since they are indicative of reduced soil loss or runoff. On the other hand, positive values imply increased soil loss on runoff. The following is an illustrative example of the combined application of Plough-Harrow and ½ Rate PM + ½ Rate NPK in the major season (Table4.4.b).

Added benefit (AB) = Y comb - (YPH–Y cont) – (YRT –Y cont) –Y cont

AB = 13.76 – (9.8 – 4.57) – (9.55 - 4.57) - 4.57

= 13.76 – (5.23) – (4.93) – 4.57

= 13.76 – 14.78

= - 1.02

3.13 Data Analysis

Data collected was subjected to analysis of variance (ANOVA) using Genstat (9th edition, 2007). The least significant difference (LSD) method at 5 % was used to determine significant differences between treatment means.

CHAPTER FOUR

4.0 RESULTS

This study was undertaken to determine soil loss, runoff, gravimetric water content, bulk density, porosity, aeration porosity, and crop yields under the four tillage practices and soil amendments. The field experiment was conducted in the minor and the major cropping seasons of 2014.

4.1 Initial physical and chemical properties of soil

Soil samples were taken at 0-15 cm depth from each experimental plot before imposition of amendments and tillage systems. The results (Table 4.1) indicated homogeneity in plots demarcated for the treatments with respect to soil properties. Apart from % clay which differed significantly ($P < 0.05$) among the tillage demarcated plots, all other plots were homogenous.

Similar results were obtained for fertility amendment demarcated plots suggesting that any difference in soil properties (fertility) among the plots in the course of the study will be due solely to application of amendments. According to Landon's rating (1991), the soil was a strongly acid sandy loam with very low organic carbon, nitrogen, potassium and of phosphorus levels. The general fertility status was thus low.

Table 4.1: Initial soil physical and chemical properties from all plots before imposition of treatment

Tillage practices	pH	OC (%)	N (%)	P (mg/kg)	K cmol (+)/kg	Sand (%)	Silt (%)	Clay (%)
Hoe-tillage	5.20	0.87	0.07	4.20	0.04	73.59	5.19	20.34
No-tillage	5.16	0.95	0.08	4.46	0.05	69.89	5.81	23.73
Plough-plant	5.19	0.94	0.08	4.27	0.04	72.48	6.73	19.79
Plough-harrow-plant	5.17	0.91	0.07	4.22	0.04	73.15	5.23	21.53
Bare	5.18	0.89	0.07	4.18	0.042	72.48	5.73	20.59
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	0.47
CV (%)	7.5	12.4	12.1	13.6	16.5	14.2	15.6	6.0
Soil fertility amendment								
Control	5.20	0.88	0.07	4.24	0.04			
% NPK	5.14	0.97	0.08	4.26	0.04			
% PM	5.22	0.88	0.08	4.30	0.05			
½ NPK+ ½ PM	5.17	0.93	0.07	4.35	0.05			
LSD (0.05)	NS	NS	NS	NS	NS			
CV (%)	12.90	16.90	15.30	17.10	17.10			

NS: not significant at the 0.05 probability level

4.2 Characterization of the poultry manure used

Results following the characterization of the poultry manure used in the experiment are shown in Table 4.2. Total N content was > 2 % whilst potassium was > 3 %. The C: N ratio was low (> 20) indicating that the manure was of high quality.

Table 4.2: Nutrients content of the poultry manure used

Total nutrients	Content
Organic carbon **(%)**	30.66
Nitrogen **(%)**	2.84
Phosphorus **(%)**	1.74
Potassium **(%)**	3.04
C/N Ratio	10.80

4.3 Rainfall amount

Total rainfall amounts recorded (Figure 4.1) at the KNUST synoptic station of the Ghana Meteorological Agency, located at about 6 km from the experiment site were respectively 464.80 mm and 385.50 mm in the major season (May to July) and minor season (September to November). The 2014 monthly rainfall amounts are presented in Appendix 1. The total annual rainfall amount was 1285.5 mm.

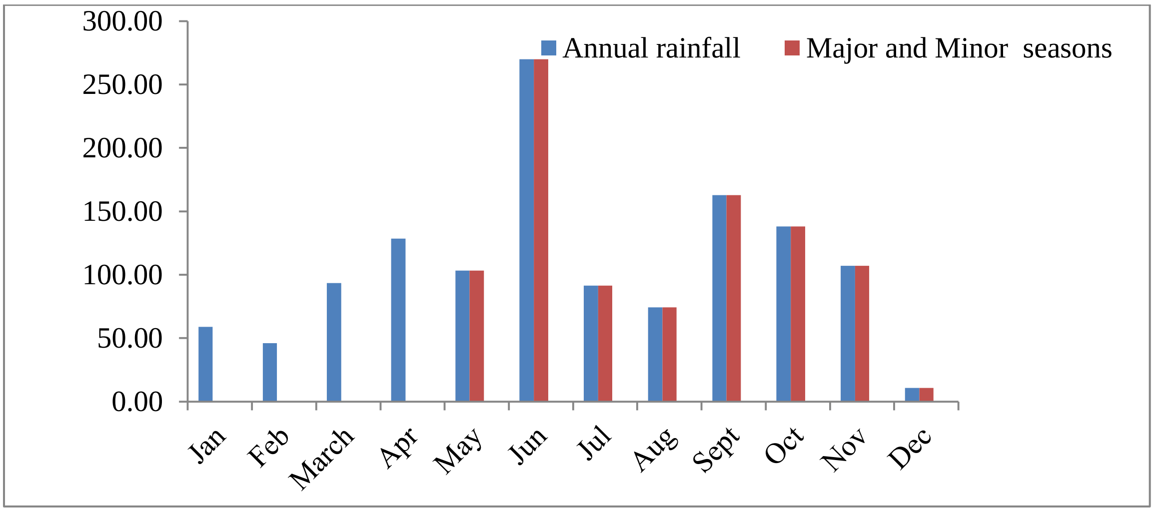


Figure 4.1: Rainfall distribution in the major and minor seasons of 2014.

4.4 Effect of tillage practices and soil amendments on soil physical properties

Soil physical properties under the four tillage treatment and soil fertility amendments were measured during the major and minor seasons (Tables 4.3a – 4.6b).

4.4.1 Gravimetric water content

Gravimetric water content varied significantly ($p < 0.05$) under the different tillage practices and soil fertility amendments in the major season (Table 4.3a) at different depths. It was observed that gravimetric water content was more in no tillage plots than all other tillage plots. Specifically gravimetric water content decreased in the order: no-tillage > plough-harrow-plant > plough-plant > hoe-tillage. In the minor season, however, the tillage practices did not differ significantly ($p > 0.05$) in gravimetric water content even though higher values were recorded under no-tillage. Gravimetric water content was not influenced significantly by soil fertility amendments in both seasons.

Table 4.3a: Influence of different tillage practices and soil fertility amendments on gravimetric water at varying soil depths in the major and minor crop growing seasons

	Gravimetric water content (%)					
Tillage practices	**Major season**			**Minor season**		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Hoe-tillage	20.07	20.36	20.76	17.98	18.81	19.46
No-tillage	23.30	23.75	23.94	19.88	20.39	21.51
Plough-plant	21.12	21.26	21.90	19.05	19.65	20.91
Plough-harrow	22.07	22.32	22.85	18.93	19.85	20.80
LSD (0.05)	0.086	0.19	0.17	NS	NS	NS
CV (%)	12.00	14.00	14.00	4.50	5.30	4.00
Soil fertility amendment						
Control	21.64	21.91	22.40	19.00	19.22	20.52
100% NPK	21.64	21.99	22.35	18.36	1962	20.31
100% PM	21.66	21.87	22.31	19.33	19.77	21.02
½ NPK+ ½ PM	21.62	21.92	22.39	19.15	20.09	20.83
LSD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	11.10	15.00	15.00	3.40	5.70	3.80

NS: not significant at the 0.05 probability level

Table 4.3b: Interaction effects of different tillage practices and soil amendments on the gravimetric water content in the major season

Gravimetric water content % in the major season				
Tillage Practices	**Soil fertility amendments**	**Depth of soil (cm)**		
		0-10	**10-20**	**20-30**
Plouh-harrow-plant	½ NPK+ ½ PM	22.11	22.39	22.92
	Control	22.01	22.31	22.85
	PM	22.04	22.21	22.83
	NPK	22.14	22.38	22.79
Hoe-tillage	½ NPK+ ½ PM	20.05	20.40	20.91
	Control	20.16	20.28	20.93
	PM	19.98	20.23	20.61
	NPK	20.09	20.52	20.67
No-tillage	½ NPK + ½ PM	23.32	23.80	23.98
	Control	23.30	23.71	23.92
	PM	23.31	23.74	23.92
	NPK	23.30	23.74	23.93
Plough-plant	½ NPK + ½ PM	21.01	21.08	21.76
	Control	21.10	21.32	21.91
	PM	21.33	21.33	21.89
	NPK	21.06	21.30	22.03
LSD (0.05)		0.17	0.23	0.22
CV (%)		11.10	5.50	8.00

4.4.2 Soil moisture storage

In the major season, soil moisture storage was significantly influenced ($p < 0.05$) by tillage practices (Table 4.4a). The highest moisture storage was consistently observed under the no-tillage system at all depths of sampling. Soil moisture stored increased with depth among the tillage treatments in the order: no-tillage > plough-harrow-plant> plough-plant> hoe-tillage. In the minor season, soil moisture storage was not influenced significantly ($P > 0.05$) by the tillage systems even though relatively higher values were recorded under the no-tillage system. As expected, values recorded in the major season were higher than in the minor season.

Table 4.4 a: Effect of different tillage practices and soil fertility amendments on soil moisture storage at varying soil depths in the major and minor crop growing seasons

	Soil moisture storage (mm)					
Tillage	**Major season**			**Minor season**		
practices	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Hoe-tillage	21.46	23.62	26.36	21.57	22.57	24.90
No-tillage	33.54	36.33	38.29	26.04	26.50	29.24
Plough-plant	22.81	25.29	29.99	22.28	23.96	27.80
Plough-harrow-plant	26.91	28.79	34.05	21.76	24.81	28.07
LSD (0.05)	1.39	1.65	1.92	NS	NS	NS
CV (%)	12.70	12.90	13.00	8.60	10.50	9.00
Soil fertility amendment						
Control	24.68	28.48	32.04	21.86	23.25	27.08
100% NPK	26.63	28.58	31.98	22.40	24.91	26.80
100% PM	26.12	27.33	33.24	23.78	24.11	28.16
½ NPK+½ PM	24.81	28.93	33.14	23.18	25.52	27.91
LSD (0.05)	NS	1.02	1.26	NS	NS	NS
CV (%)	15.80	14.30	14.70	5.40	10.60	6.30

NS: not significant at the 0.05 probability level

In the major season, soil fertility amendment options significantly ($p < 0.05$) influenced soil moisture storage at all depths of sampling except the top layer (0-10 cm). The highest values were generally recorded under 100% NPK whilst the least under the control. In the minor season, the different fertility amendments had no significant impact ($p < 0.05$) on soil moisture stored at all depths of sampling (Table 4.4b).

Tillage and soil fertility amendments interacted to significantly influence ($P<0.05$) soil moisture stored at all depths (Table 4.4b). The greatest soil moisture was stored under no-tillage and 100% NPK at 0-10 cm; no-tillage and 100% PM at 10-20 cm and no-tillage and ½ NPK+ ½ PM plots at 20-30 cm.

Table 4.4b: Interaction effects of different tillage practices and soil amendments on soil moisture storage in the major season

	Soil moisture storage (mm)			
Tillage Practices	**Soil fertility amendments**	**Major season Depth of soil** (cm)		
		0-10	**10-20**	**20-30**
Plouh-harrow-plant	½ NPK+ ½ PM	24.99	27.09	32.08
	Control	28.61	29.67	35.65
	PM	26.88	29.53	35.16
	NPK	27.23	28.87	33.50
Hoe-tillage	½ NPK+½ PM	21.25	22.84	26.55
	Control	21.17	22.52	25.32
	PM	21.37	23.86	25.96
	NPK	21.69	25.45	27.90
No-tillage	½ NPK+½ PM	31.72	35.22	38.36
	Control	34.48	36.98	38.51
	PM	33.33	37.27	38.51
	NPK	34.72	35.62	37.33
Plough-plant	½ NPK+½ PM	21.43	25.30	28.72
	Control	23.42	27.28	29.36
	PM	22.60	23.67	32.62
	NPK	23.58	24.93	29.07
LSD (0.05)		2.46	2.25	2.70
CV (%)		11.20	9.00	11.12

4.4.3 Bulk Density

There were significant differences ($p < 0.05$) among the treatments with regard to bulk density at various depths in the major season (Table 4.5a). The no tillage practice recorded the highest bulk density whilst the lowest bulk density was recorded under hoe tillage.

Like tillage practices, the different soil amendments had significant ($p < 0.05$) impacts on soil bulk density at the different depths of sampling in the major season.

Bulk density increased with depth in both seasons of the study. The tillage practices and soil fertility amendments interacted significantly to affect bulk density in the major season at all depths (Table 4.5b).

Table 4.5a: Effect of different tillage practices and soil fertility amendments on bulk density at varying soil depths

	Bulk density (Mg m^{-3})					
Tillage	**Major season**			**Minor season**		
practices	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Hoe-tillage	1.07	1.16	1.27	1.20	1.20	1.28
No-tillage	1.44	1.53	1.60	1.31	1.30	1.36
Plough-plant	1.08	1.19	1.37	1.17	1.22	1.33
Plough-harrow-plant	1.22	1.29	1.49	1.15	1.25	1.35
LSD (0.05)	0.059	0.076	0.09	NS	NS	NS
CV (%)	12.50	13.00	13.40	7.20	8.40	6.90
Soil fertility amendment						
Control	1.14	1.30	1.43	1.15	1.21	1.32
100% NPK	1.23	1.30	1.43	1.22	1.27	1.32
100% PM	1.20	1.25	1.40	1.23	1.22	1.34
½ NPK+½ PM	1.24	1.32	1.48	1.21	1.27	1.34
LSD (0.05)	0.05	0.04	0.05	NS	NS	NS
CV (%)	15.40	14.50	14.60	4.70	6.80	5.30

NS: not significant at the 0.05 probability level

Table 4.5b: Interaction effect of different tillage practices and soil amendments at varying soil depths on bulk density in the major and minor crop growing seasons

Bulk Density (Mg m^{-3})				
Tillage practices	**Soil fertility amendments**	**Major season Depth of soil** (cm)		
		0-10	**10-20**	**20-30**
Plough-harrow-plant	½ NPK+ ½ PM	1.13	1.21	1.40
	Control	1.30	1.33	1.56
	PM	1.22	1.33	1.54
	NPK	1.23	1.29	1.47
Hoe-tillage	½ NPK+½ PM	1.06	1.12	1.27
	Control	1.05	1.11	1.21
	PM	1.07	1.18	1.26
	NPK	1.08	1.24	1.35
No-tillage	½ NPK+½ PM	1.36	1.48	1.60
	Control	1.48	1.56	1.61
	PM	1.43	1.57	1.61
	NPK	1.49	1.50	1.56
Plough-plant	½ NPK+½ PM	1.02	1.20	1.32
	Control	1.11	1.28	1.34
	PM	1.06	1.11	1.49
	NPK	1.12	1.17	1.32
LSD (0.05)		0.11	0.10	0.12
CV (%)		10.60	6.00	7.00

4.4.4 Total porosity and aeration porosity

The analysis of variance showed that tillage practices caused significant differences ($p < 0.05$) in porosity and aeration porosity at all depths in the major season (Table 4.6a and 4.6c). No-tillage had the lowest total porosity and aeration porosity at all depths whilst hoe-tillage had the highest. Differences in total porosity and aeration porosity among the tillage practices in minor season were however, not significant ($p > 0.05$).

Soil fertility amendments like the tillage practices influenced total porosity only in the major season at all depths (Table 4.6a and 4.6b). Similarly, aeration porosity was significantly influenced by the soil fertility amendments in the major season (Table 4.6c). Interaction effects on total porosity and aeration porosity were significant in the major season at all depths (Table 4.6b and 4.6d). ½ NPK + ½ PM had higher total porosity under all tillage except No- tillage and was significantly higher under the control plot.

Table 4.6a: Influence of different tillage practices and soil fertility amendments on total porosity in the major and minor crop growing seasons

	Total porosity (%)					
Tillage	**Major season**			**Minor season**		
practices	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Hoe-tillage	59.62	56.22	52.07	54.71	54.71	51.69
No-tillage	45.68	42.26	39.62	50.56	50.94	48.68
Plough-plant	59.24	55.06	48.30	55.84	53.96	49.81
Plough-harrow-plant	53.96	51.32	43.77	56.60	52.83	49.05
LSD (0.05)	2.25	2.89	3.66	NS	NS	NS
CV (%)	12.10	12.80	14.00	6.50	7.40	7.00
Soil fertility amendment						
Control	56.98	50.94	46.03	56.60	54.33	50.18
100% NPK	53.59	50.94	46.04	53.96	52.07	50.18
100% PM	54.72	52.83	47.16	53.58	53.96	49.43
½ NPK+½ PM	53.21	50.19	44.15	54.33	52.07	49.81
LSD (0.05)	2.06	1.83	2.09	NS	NS	NS
CV (%)	14.50	14.20	15.00	4.30	6.00	5.30

NS: not significant at the 0.05 probability level

Table 4.6b: Interaction of different tillage practices and soil amendments at varying soil depths on total porosity in the major season

Total porosity (%)				
Tillage practices	**Soil fertility amendments**	**Major season Depth of soil** (cm)		
		0-10	**10-20**	**20-30**
Plough-harrow-plant	½ NPK+½ PM	57.36	54.34	47.16
	Control	50.94	49.81	41.13
	PM	53.96	49.81	41.89
	NPK	53.58	51.32	44.52
Hoe-tillage	½ NPK+½ PM	60.00	57.73	52.08
	Control	60.38	58.11	54.33
	PM	59.62	55.47	52.45
	NPK	59.24	53.20	49.05
No-tillage	½ NPK+½ PM	48.67	44.15	39.62
	Control	44.15	41.13	39.24
	PM	46.03	40.75	39.25
	NPK	43.77	43.40	41.13
Plough-plant	½ NPK+½ PM	61.51	54.72	50.18
	Control	58.11	51.69	49.43
	PM	60.00	58.11	43.77
	NPK	57.73	55.85	50.19
LSD (0.05)		4.61	3.99	4.78
CV (%)		10.50	5.50	8.00

Table 4.6c: Aeration porosity as influenced by tillage practices and soil fertility amendments in the major and minor crop growing seasons

	Aeration porosity (%)					
Tillage practices	**Major season**			**Minor season**		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Hoe-tillage	38.16	32.60	25.71	33.14	32.26	23.19
No-tillage	12.14	6.63	11.33	28.00	24.34	23.44
Plough-plant	36.43	29.77	18.31	33.56	30.16	22.01
Plough-harrow-plant	27.05	22.53	19.72	33.84	28.10	20.98
LSD (0.05)	3.64	4.52	5.29	NS	NS	NS
CV (%)	6.40	10.00	18.20	19.50	21.80	26.00
Soil fertility amendment						
Control	32.30	22.46	13.99	33.74	30.70	23.10
100% NPK	26.96	22.36	14.06	31.56	27.34	23.38
100% PM	28.60	25.50	13.92	29.80	30.09	21.27
½ NPK+½ PM	26.00	21.26	23.10	31.15	26.73	21.90
LSD (0.05)	3.34	2.84	3.69	NS	NS	NS
CV (%)	13.90	14.90	27.90	12.50	19.50	18.70

NS: not significant at the 0.05 probability level

Table 4.6d: Interaction of different tillage practices and soil amendments at varying soil depths on aeration porosity in the major season

Aeration porosity (%)				
Tillage Practices	**Soil fertility amendments**	**Major season Depth of soil** (cm)		
		0-10	**10-20**	**20-30**
Plough-harrow-plant	½ NPK+½ PM	32.37	27.25	15.08
	Control	22.33	20.14	15.48
	PM	27.08	22.30	16.73
	NPK	26.35	22.45	20.52
Hoe-tillage	½ NPK+½ PM	38.75	34.89	25.52
	Control	39.20	35.60	29.01
	PM	38.25	31.61	26.49
	NPK	37.55	27.75	21.15
No-tillage	½ NPK+½ PM	16.95	18.93	10.26
	Control	9.67	14.15	10.73
	PM	12.7	13.48	10.74
	NPK	9.05	17.78	13.80
Plough-plant	½ NPK+ ½ PM	40.08	29.42	21.46
	Control	34.69	24.41	20.07
	PM	37.19	34.44	11.15
	NPK	34.15	30.92	21.12
LSD (0.05)		6.48	6.21	7.39
CV (%)		1.90	12.10	11.40

4.4.5 Soil depth reduction due to soil loss

Soil depth reduction due to cumulative soil loss from the different tillage practices and soil fertility amendments are presented in Table 4.7a. The reduction in soil depth was in the order: no-tillage < plough-plant < plough-harrow-plant < bare plot < hoe-tillage. Under soil fertility amendments, the reduction in soil depth was in the order: 100% NPK < ½ NPK+½ PM < 100% PM < control in both seasons. Soil depth reduction was significantly influenced ($p < 0.05$) by both tillage and amendments in the major and minor seasons. Tillage x amendment interaction with respect to soil depth reduction was significant in both seasons. The greatest reduction in depth was observed under control and hoe-tillage in the major season and, hoe-tillage and 100% NPK plots in the minor season (Table 4.7b).

Table 4.7a: Soil depth reduction due to soil loss in the major and minor crop growing seasons of 2014

	Soil depth reduction due to soil loss (mm)		
Tillage practices	**Major season**	**Minor season**	**Cumulative**
Hoe-tillage	7.75	1.84	9.59
No-tillage	1.67	0.58	2.25
Plough-plant	4.22	0.94	5.16
Plough-harrow-plant	4.52	1.13	5.65
Bare plot	6.00	4.95	10.95
LSD (0.05)	0.69	0.28	1.21
CV (%)	6.50	11.20	4.5
Soil fertility amendment			
Control	5.46	1.05	6.51
100% NPK	3.73	1.18	4.87
100% PM	4.60	1.16	5.76
½ NPK- ½ PM	4.38	1.14	5.52
LSD (0.05)	1.01	NS	1.50
CV (%)	7.60	12.70	12.4

NS: not significant at the 0.05 probability level

Table 4.7b: Interaction of different tillage practices and soil fertility amendments on depth reduction in major and minor seasons

	Soil depth reduction due to soil loss (mm)		
Tillage Practices	**Soil fertility amendments**	**major season**	**Minor season**
Plough-harrow-plant	½ NPK+½ PM	3.54	1.13
	Control	5.98	1.36
	PM	5.67	1.20
	NPK	2.90	0.81
Hoe-tillage	½ NPK+½ PM	8.16	1.61
	Control	9.49	1.72
	PM	6.49	1.97
	NPK	6.85	2.06
No-tillage	½ NPK+½ PM	0.80	0.45
	Control	2.66	0.50
	PM	1.65	0.56
	NPK	1.58	0.79
Plough-plant	½ NPK+½ PM	5.00	1.37
	Control	3.69	0.62
	PM	4.59	0.89
	NPK	3.60	0.87
LSD (0.05)		1.83	0.41
CV (%)		26.50	20.60

4.5 Runoff under tillage practices and soil amendments

Table 4.8a presents the impact of tillage and soil amendment on total runoff. The respective values for runoff as affected by tillage for the major and minor seasons ranged from 4.90 to 11.97 and 0.77 to 0.79 respectively. The tillage practices significantly ($p < 0.05$) affected runoff in the major season but not in the minor season. In the major season, the hoe-tillage recorded higher ($p < 0.05$) runoff than all the other tillage practices (except the plough-harrow-plant). The least runoff was recorded under no-tillage. The decreasing order of runoff as affected by tillage in the major season was hoe-tillage> plough-harrow-plant> plough-plant> no-tillage.

The bare plot however generated higher runoff than the tilled plots in both seasons. The percent increase of runoff on the bare plot over the hoe-tillage, plough-harrow-plant, plough-plant and no-tillage were 22.50, 36.40, 41.70 and 68.30, and 173.40, 180.50, 173.40 and 173.40 for the major and minor season respectively. The cumulative runoff was in the order of hoe-tillage> plough-harrow-plant> plough-plant> no-tillage with values ranging from 5.67 to 12.69.

The soil amendments significantly ($p < 0.05$) influenced runoff in the major season but not in the minor season with values ranging from 6.37 to 12.51 and 0.78 to 0.80 for the major and minor seasons respectively. The respective decreasing order of runoff under the soil amendments in the major and minor seasons were control > ½ NPK- ½ PM > 100% PM > 100% NPK and control > 100% PM > 100% NPK> ½ NPK- ½ PM. In the major season, the 100% NPK and 100% PM generated the least runoff whilst the highest was generated under the control. The percent increase in runoff under the control over NPK, PM and ½ NPK- ½ PM in the major and minor seasons were 96.40, 69.10 and 31.00, and 2.56, 1.26 and 3.89 respectively. The cumulative impact of the soil amendments on runoff generation over the two seasons were in the order of control > ½ NPK- ½ PM > 100% PM > 100% NPK with values ranging between 7.15 and 13.31.

The interaction effect of tillage and soil amendments (Table 4.8 b) significantly ($p < 0.05$) affected runoff generation in both seasons. In the major season, the no-tillage x ½ NPK- ½ PM and plough-harrow-plant x control generated the least and highest runoff respectively whilst the least runoff in the minor season was recorded under plough-harrow-plant x ½ NPK- ½ PM and plough-plant x ½ NPK- ½ PM, and the highest was recoded under plough-harrow-plant x control. Application of the soil amendments significantly reduced runoff except in some few cases in the major season. Except under no-tillage x 100% NPK interaction, the interaction between 100% NPK fertilizer and the tillage practices generated the least runoff, although, some of the differences recorded were not significant. In the minor season the impact of soil amendments on runoff generation was different under each tillage practice with some doing better than others. In the major season, the impact of soil amendments on runoff was lower under the plough-harrow-plant than the other tillage practices. Its impact on tillage did not give any particular trend in the minor season with some soil amendments performing better in reducing runoff under certain tillage practices but not under others.

Table 4.8a: Influence of different tillage practices and soil fertility amendments on total runoff

	Total runoff (mm)		
Tillage practices	**Major season**	**Minor season**	**Cumulative**
Hoe-tillage	11.97	0.79	12.69
No-tillage	4.90	0.77	5.67
Plough-plant	9.00	0.79	9.79
Plough-harrow-plant	9.80	0.79	10.59
Bare	15.45	2.16	17.61
LSD (0.05)	2.51	NS	7.62
CV (%)	7.10	1.50	15.8
Soil fertility amendment			
Control	12.51	0.80	13.31
100% NPK	6.37	0.78	7.15
100% PM	7.40	0.79	8.19
½ NPK- ½ PM	9.55	0.77	10.32
LSD (0.05)	2.10	NS	4.31
CV (%)	14.10	3.00	14.40

NS: not significant at the 0.05 probability level

Table 4.8b: Interaction of different tillage practices and soil fertility amendments on total runoff in the major and minor seasons

		Total runoff (mm)	
Tillage Practices	**Soil fertility amendments**	**Major season**	**Minor season**
Plough-harrow-plant	½ NPK+ ½ PM	13.76	0.74
	Control	19.47	0.88
	PM	3.22	0.78
	NPK	2.83	0.77
Hoe-tillage	½ NPK+½ PM	12.10	0.81
	Control	12.99	0.75
	PM	13.58	0.80
	NPK	9.21	0.77
No-tillage	½ NPK+½ PM	2.53	0.78
	Control	4.57	0.75
	PM	3.84	0.77
	NPK	8.67	0.78
Plough-plant	½ NPK+½ PM	9.40	0.74
	Control	13.01	0.82
	PM	8.97	0.80
	NPK	4.76	0.77
LSD (0.05)		4.16	0.08
CV (%)		27.90	6.00

An assessment was made to show the benefits obtained when the soil amendments were combined with tillage (Table 4.8c). In the major season, the combination of soil amendments and tillage added sufficient benefits with the Plough-harrow x 100% PM recording the highest benefit. Addition of ½ NPK+½ PM to the Plough-harrow-plant recorded the least benefit.

In the minor season, except in some few cases, the combination of soil amendments and tillage were beneficial with the plough-plant x ½ NPK+½ PM and Plough-harrow x ½ NPK+½ PM recording the highest benefits.

Table 4.8c: The added benefit from combined application of amendment and tillage practices on runoff

Tillage x amendment	Added benefit runoff (mm ha^{-1})	
	Major	Minor
Plough-harrow x ½ NPK+ ½ PM	-1.02	-0.04
Plough-harrow x 100% NPK	-8.77	-0.02
Plough-harrow x 100% PM	-9.41	-0.02
Hoe-tillage x ½ NPK+ ½ PM	-4.85	0.03
Hoe-tillage x 100% NPK	-4.56	-0.02
Hoe-tillage x 100% PM	-1.22	0
Plough-plant x ½ NPK+ ½ PM	-4.58	-0.04
Plough-plant x 100% NPK	-6.04	-0.02
Plough-plant x 100% PM	-2.86	0

4.6 Soil loss under tillage practices and soil amendments

The effect of the tillage practices on soil loss in the major and minor seasons are shown in Table 4.9a. More eroded sediments were transported under the tilled plots than the untilled plots (no-tillage) in the major and minor season. In the major season, the lowest soil loss was recorded under no-tillage followed by plough-plant, plough-harrow-plant and hoe-tillage in that increasing order. Soil loss under the hoe tillage was 37 to 79% greater than the other tillage practices. The trend did not change in the minor season except for magnitude. In both seasons, soil loss under the bare plots were considerably higher than the tilled plots. Soil loss in the major season was greater than in the minor season (Table 4.9a).

The applied soil amendments significantly ($P > 0.05$) influenced the amount of sediments transported in the soil loss in the major season but not in the minor season.

In the major season, the lowest soil loss was observed under 100% NPK treatment and the highest on the control plots. Soil loss ranged from 2.99 to 4.63 and 0.91 to 0.94 in the major and minor seasons respectively.

The results indicated significant differences ($p < 0.05$) among tillage practices x soil amendments interactions in both seasons (Table 4.9b). The tillage x soil amendment interaction values ranged from 0.76 Mg ha^{-1} to 7.78 Mg ha^{-1} in the major season and 0.34 to 1.48 Mg ha^{-1} in the minor season. In both seasons, the highest soil loss was recorded under the unfertilized hoe-tillage plots. Whilst the interaction between ½ PM + ½ NPK and no tillage led to lower soil loss in the major season, the interaction between the control and no-tillage recorded the least soil loss in the minor season. Generally, the tillage x control interactions means showed higher soil loss in the major season than in the minor season.

Table 4.9a: Effect of different tillage practices and soil fertility amendment on total soil loss in the major and minor crop growing seasons of 2014

	Soil Loss (Mg ha^{-1})		
Tillage practices	**Major season**	**Minor season**	**Cumulative**
Hoe-tillage	6.44	1.43	7.87
No-tillage	1.36	0.48	1.83
Plough-plant	3. 39	0.75	4.14
Plough-harrow-plant	4.05	1.01	5.07
Bare	7.14	1.50	8.64
LSD (0.05)	0.63	0.26	1.30
CV (%)	7.10	11.20	4.50
Soil fertility amendment			
Control	4.63	0.91	5.54
100% NPK	2.99	0.91	3.91
100% PM	3.86	0.94	4.80
½ NPK- ½ PM	3.75	0.91	4.66
LSD (0.05)	0.81	NS	1.19
CV (%)	8.20	14.00	14.10

NS: not significant at the 0.05 probability level

Table 4.9b: Interactions of different tillage practices and soil fertility amendments on total soil loss in the major and minor seasons

		Soil Loss (Mg ha^{-1})	
Tillage Practices	**Soil fertility amendments**	**Major season**	**Minor season**
Plough-harrow-plant	½ NPK+ ½ PM	2.91	0.94
	Control	5.61	1.28
	PM	2.63	1.10
	NPK	5.04	0.74
Hoe-tillage	½ NPK+½ PM	7.75	1.23
	Control	7.78	1.48
	PM	5.17	1.46
	NPK	5.07	1.54
No-tillage	½ NPK+½ PM	0.76	0.43
	Control	1.80	0.34
	PM	1.52	0.46
	NPK	1.35	0.64
Plough-plant	½ NPK+½ PM	3.59	1.03
	Control	3.33	0.54
	PM	3.71	0.72
	NPK	2.92	0.71
LSD (0.05)		1.49	0.34
CV (%)		25.20	19.60

The benefits obtained from the combination of soil amendments and tillage practices are presented Table 4.9c. Substantial benefits were obtained from the combinations except in the hoe-tillage x ½ NPK + ½ PM in the major season where a negative impact was recorded. The Plough-harrow x 100% NPK and hoe-tillage x 100% NPK recorded the highest benefits in the major and minor seasons respectively. The respective range for added benefits in the major and minor seasons were 1.75 to -5 and -3.67 to -7.19.

Generally, higher benefits were obtained in the minor season than the major season.

Table 4.9c: The added benefit from combined application of amendment and tillage practices on soil loss

Tillage x amendment	Added benefit for soil loss (Mg ha^{-1})	
	Major	Minor
Plough-harrow x ½ NPK+ ½ PM	-3.09	-4.88
Plough-harrow x 100% NPK	-5.00	-4.52
Plough-harrow x 100% PM	-0.38	-7.19
Hoe-tillage x ½ NPK+ ½ PM	1.75	-6.89
Hoe-tillage x 100% NPK	-5.00	-6.97
Hoe-tillage x 100% PM	-2.53	-3.67
Plough-plant x ½ NPK+ ½ PM	-2.41	-3.67
Plough-plant x 100% NPK	-4.71	-3.99
Plough-plant x 100% PM	-1.74	-3.98

4.7 Plant growth, plant logging, dry biomass weight and grain yield under tillage practices and soil amendments

4.7.1 Plant Height

Plant height is an important growth parameter directly linked with productive potential of plant in terms of fodder and grain. The effect of tillage practices and soil fertility amendments on maize plant height is presented in Table 4.10a. Analysis of variance showed significant differences ($p < 0.05$) among the tillage practices at all periods of sampling. The tallest plants were observed under no-tillage system whilst the shortest plants were located on hoe-tillage plots throughout the study period.

Over the course of the study, analysis of variance showed no significant differences in plant height between the different soil fertility amendments. There was no significant ($P < 0.05$) tillage x soil fertility amendments interaction effect in the major growing season. A similar observation was made in the minor growing season.

Table 4.10a: Influence of different tillage practices and soil fertility amendments on plant height

	Plant Height (cm)			
Tillage practices	**Major season**		**Minor season**	
	6 WAP	**8WAP**	**6WAP**	**8WAP**
Hoe-tillage	123.00	152.10	122.50	150.80
No-tillage	152.59	195.90	149.30	180.70
Plough-plant	133.48	175.20	129.30	171.30
Plough-harrow-plant	129.60	169.20	134.70	151.40
LSD (0.05)	5.90	19.65	7.06	19.18
CV (%)	11.10	3.70	2.60	12.10
Soil fertility amendment				
Control	131.78	171.50	132.30	158.20
100% NPK	135.57	173.50	133.30	164.00
100% PM	133.37	173.10	133.50	161.60
½ NPK- ½ PM	137.95	174.30	136.70	170.10
LSD (0.05)	NS	NS	NS	NS
CV (%)	2.20	5.70	6.00	5.90
Interaction (T×A)	NS	NS	NS	NS

NS: not significant at the 0.05 probability level; **T x A:** Interaction effect of tillage and soil amendments

4.7.2 Plant logging

The data (Table 4.10b) showed the influence of tillage on plant logging during the major season. Plant logging was highest on plough-plant and plough-harrow-plant plots whilst the least was observed on no-tillage plots. Soil fertility amendments produced similar effects ($P > 0.05$) on plant logging in the major season of cropping. Tillage and amendment effect was also not significant ($P > 0.05$).

Table 4.10b: Influence of different tillage practices and soil fertility amendments on number of plant logged in the major crop growing season

	Number of plants logged
Tillage practices	**Major season**
Hoe-tillage	6.0
No-tillage	3.8
Plough-plant	6.8
Plough-harrow-plant	6.8
LSD (0.05)	1.2
CV (%)	16.03
Soil fertility amendment	
Control	6.0
100% NPK	5.8
100% PM	6.1
½ NPK- ½ PM	5.5
LSD (0.05)	NS
CV (%)	10.60
Interaction (T×A)	NS

NS: not significant at the 0.05 probability level; **T x A:** Interaction effect of tillage and soil amendments

4.7.3 Biomass (dry weight) and grain yield

The effect of tillage practices and soil fertility amendments on dry biomass is shown in Table 4.10c. Maize biomass (dry weight) was highest under no-tillage practice in both major and minor cropping seasons while the lowest biomass was found on hoe tillage plots in the major season. In the minor season, the lowest biomass was recorded on the plough-harrow-plant. Biomass varied significantly ($P < 0.05$) due to application of organic manure and inorganic fertilizers in both seasons. In the major season, plants that received ½ NPK+½ PM fertilizer produced the highest biomass

(8261 kg ha^{-1}) while plants on the control plot had the lowest (7175 kg ha^{-1}). The same trend was observed in the minor season. There were however, no marked differences ($P > 0.05$) between tillage practices x soil fertility amendment interactions.

Table 4.10d indicates the mean yield of maize under the various tillage practices in the major and minor cropping seasons. There were significant differences ($P < 0.05$) between the different tillage practices with respect to grain yield. No-tillage produced the highest grain yield of 1413 kg ha^{-1} while hoe tillage recorded the least value of 563 kg ha^{-1} in the major season. The average yield from the tillage practices however, was 967.75 kg ha^{-1}.

Maize yield under sol fertility amendments is shown in Table 4.10d. There were significant differences ($P < 0.05$) between the different fertility amendments. In the major season, plants that received ½ NPK+ ½ PM fertilizer produced the highest yield of maize (1213 kg ha^{-1}), while the control had the lowest yield (699 kg ha^{1}). There were no significant differences ($P > 0.05$) between tillage practices x soil fertility amendment interactions in both seasons. Maize grain yield under the different tillage systems and fertility amendments were higher in the major season than in the minor season (Table 4.10d).

Table 4.10c: Influence of different tillage practices and soil fertility amendments on dry biomass weight in the major and minor crop growing seasons of 2014

	Dry biomass weight (kg ha^{-1})	
Tillage practices	**Major season**	**Minor season**
Hoe-tillage	7043	4081
No-tillage	8820	7471
Plough-plant	8031	5595
Plough-harrow-plant	7274	3752
LSD (0.05)	775	680
CV (%)	11.90	4.50
Soil fertility amendment		
Control	7175	4542
100% NPK	7866	5101
100% PM	7866	4970
½ NPK+½ PM	8261	6286
LSD (0.05)	531	858
CV (%)	5.00	6.50
Interaction (T×A)	NS	NS

NS: not significant at the 0.05 probability level; **T x A:** Interaction effect of tillage and soil amendments

Table 4.10d: Influence of different tillage practices and soil fertility amendments on grain yield of maize

	Grain yield (kg ha^{-1})	
Tillage practices	**Major season**	**Minor season**
Hoe-tillage	563	571
No-tillage	1413	918
Plough-plant	1110	636
Plough-harrow-plant	785	471
LSD (0.05)	421	227
CV (%)	7.50	7.50
Soil fertility amendment		
Control	699	404
100% NPK	895	649
100% PM	1063	566
½ NPK+ ½ PM	1213	977
LSD (0.05)	282	203
CV (%)	21.80	17.50
Interaction (T×A)	NS	NS

NS: not significant at the 0.05 probability level; **T x A:** Interaction effect of tillage and soil amendments

4.8 Relationships between parameters

4.8.1 Relationship between rainfall and soil loss

Figures 4.2a and 4.2b showed that soil loss positively correlated with rainfall. Soil loss thus increased as rainfall amount increased with a coefficient of determination (R^2) ranging from 0.43, 0.55, 0.57, 0.59 and 0.77 respectively for no-tillage, plough-plant, hoe-tillage, plough-harrow-plant, and bare plots in the major season. A similar trend was observed in the minor season with R^2 values ranging from 0.63 to 0.74 (Figure 4.2b).

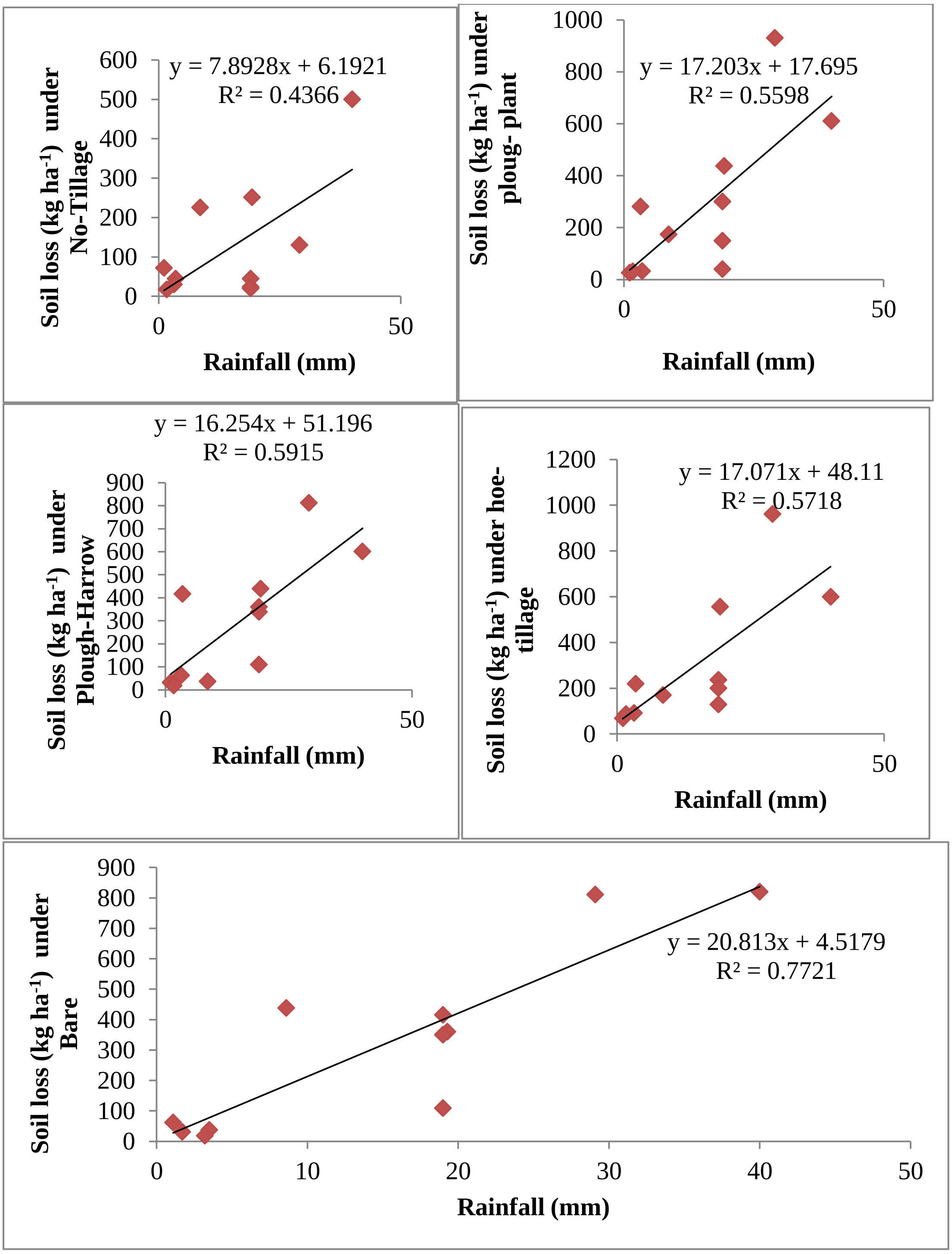


Figure 4.2a: Relationship between rainfall and soil loss during the major cropping season

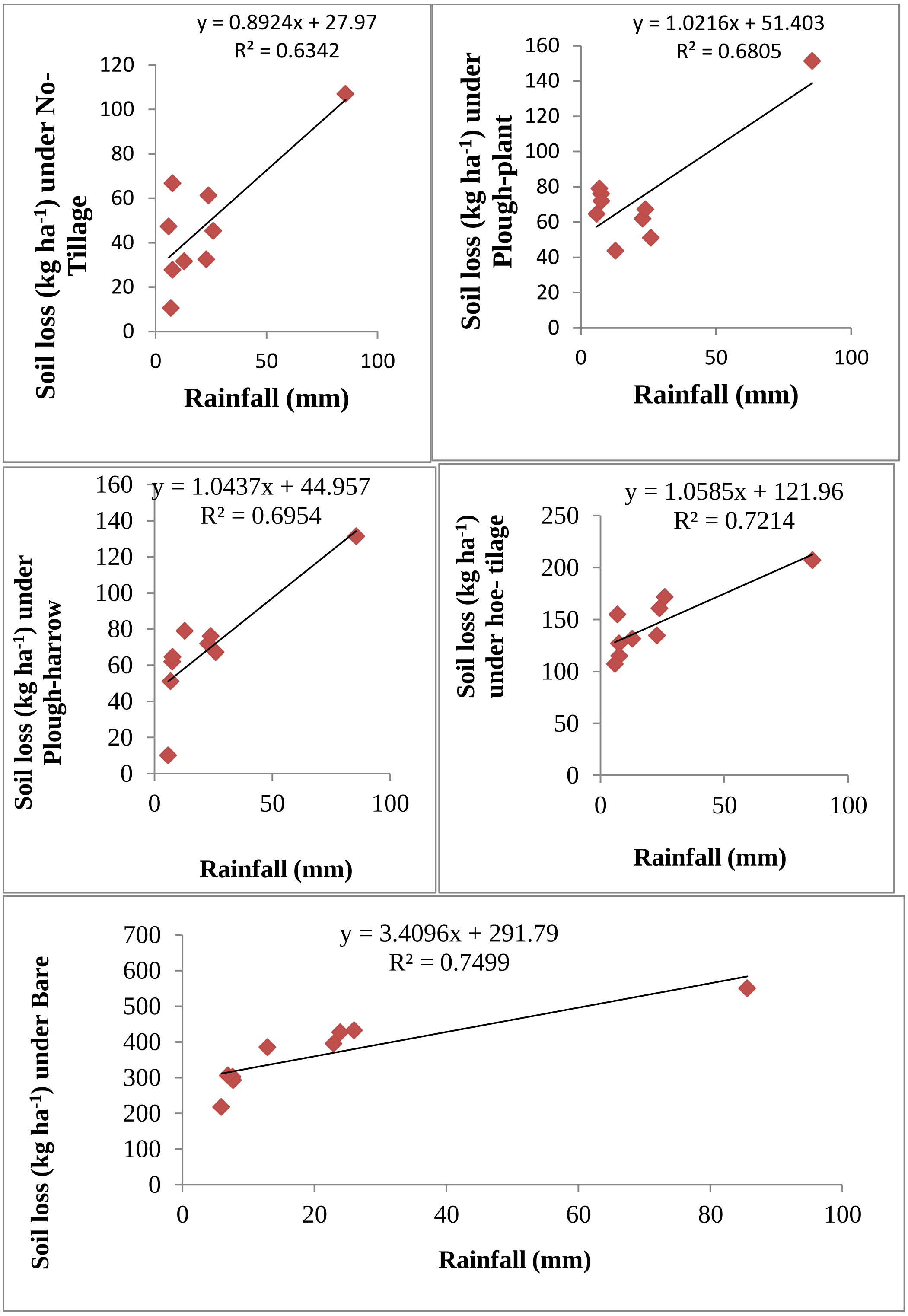


Figure 4.2b: Relationship between rainfall and soil loss during the minor cropping season in 2014

4.8.2 Relationship between rainfall and runoff

The amount of runoff generated increased with increasing rainfall. The runoff volume varied with the type of tillage (Figure 4.3a, 4.3b). The coefficient of determination (R^2) varied from 0.55 to 0.79 in the major season and 0.59 to 0.76 in the minor season.

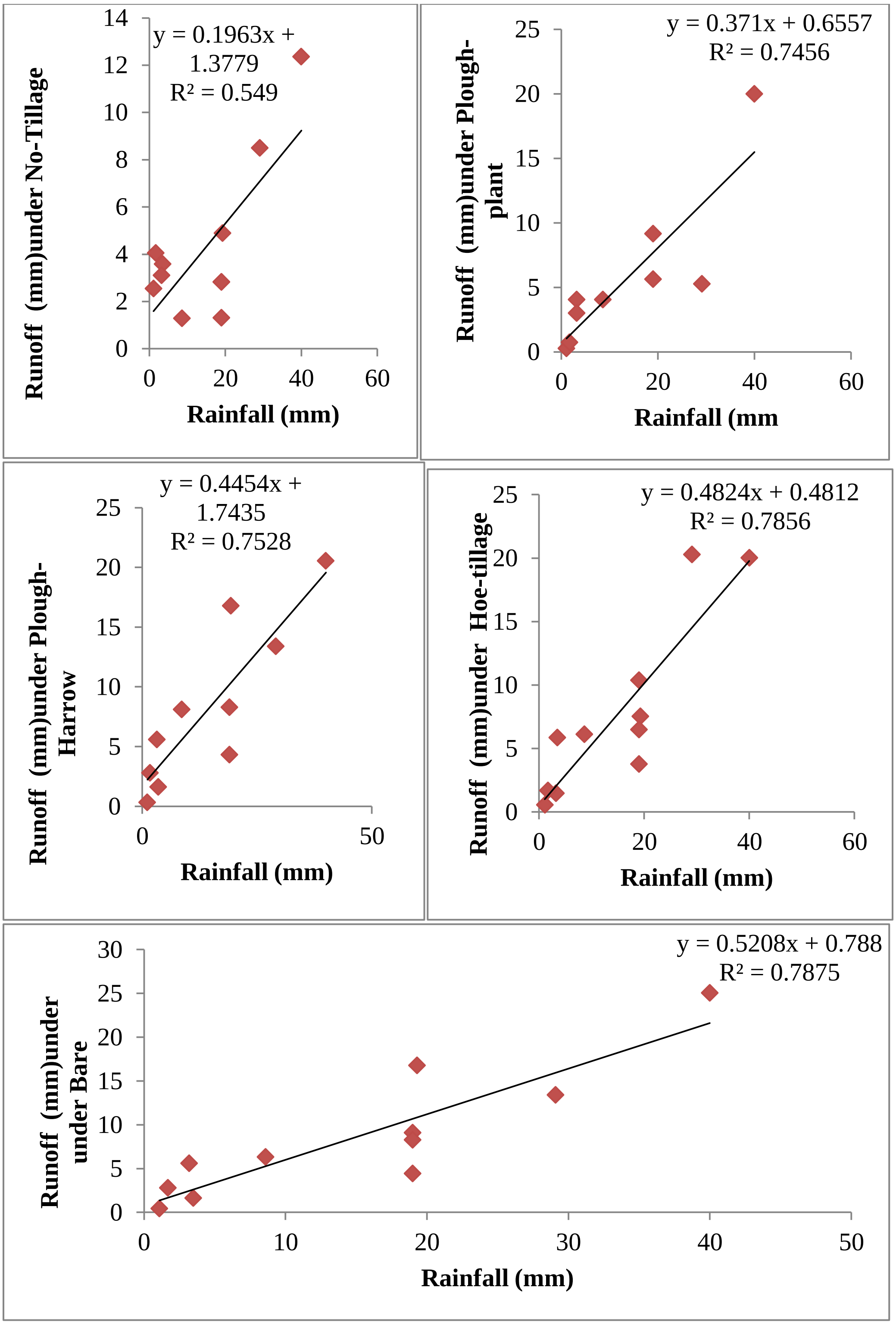


Figure 4.3a: Relationship between rainfall and runoff during the major season cropping in 2014

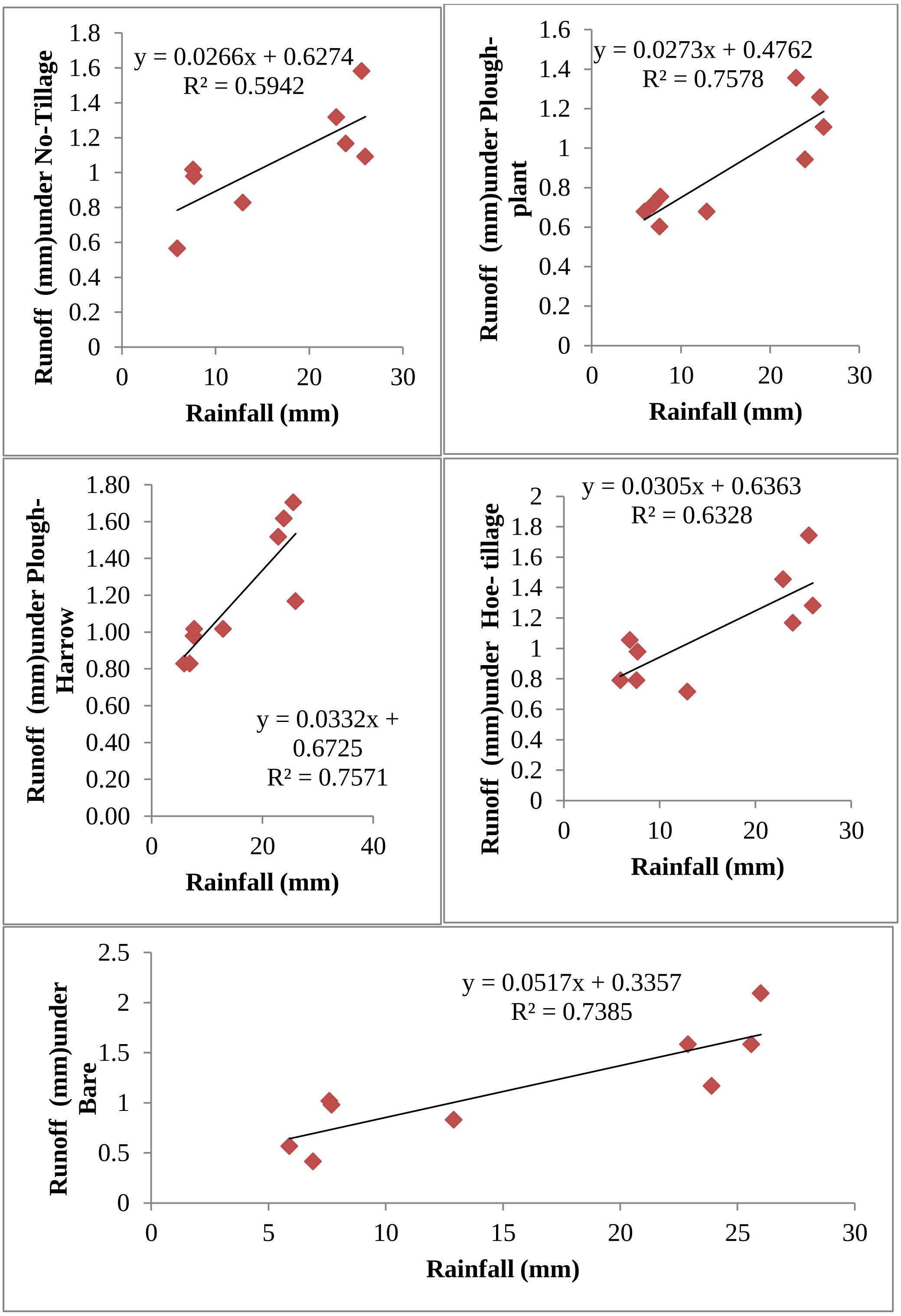


Figure 4.3b: Relationship between rainfall and runoff during the minor cropping season in 2014

4.8.3 Relationship between runoff and soil loss

Runoff and soil loss were positively correlated as presented in Figure 4.4. The coefficient of determination was 0.94 in the major season.

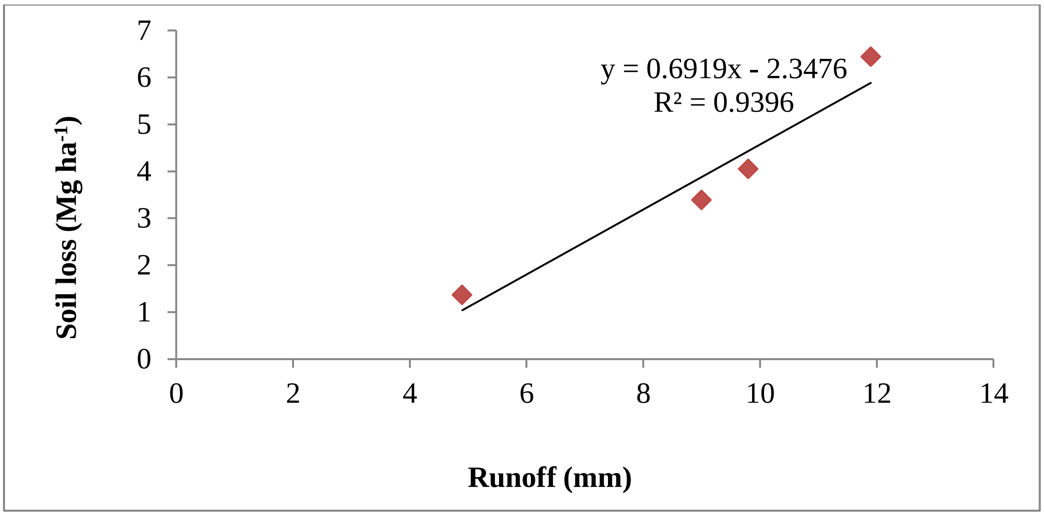


Figure 4.4: Relationship between runoff and soil loss in the major season

4.8.9 Relationship between soil loss and maize yield

The Figure 4.5 shows that soil loss had a negative impact on maize yield, implying that when soil loss increased, the maize yield decreased in the major and minor seasons. The coefficients of determinations were respectively 0.93 and 0.55.

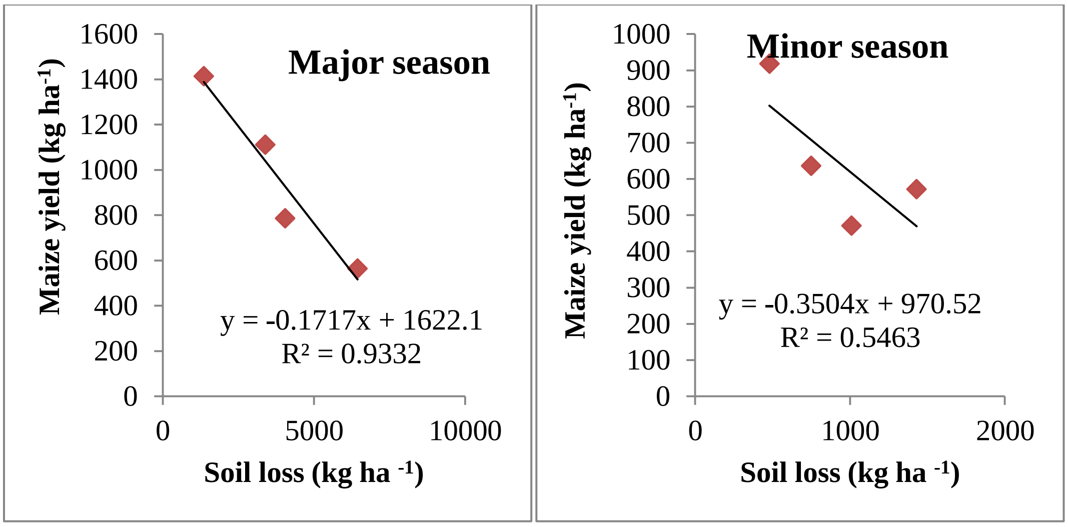


Figure 4.5: Relationship between soil loss and maize yield

4.8.11 Relationship between depth reduction and maize yield

The Figure 4.6 shows that soil depth reduction due to soil loss had negative impact on maize yield. The coefficients of determination in the major and minor season were respectively 0.89 and 0.43. There was thus better correlation in the major than in the minor season.

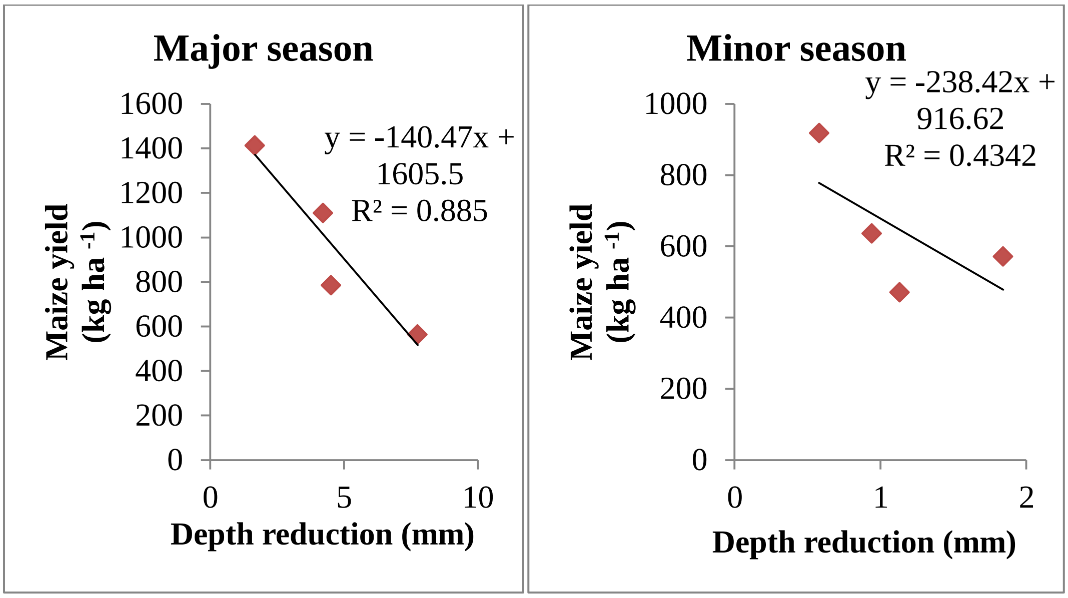


Figure 4.6: Relationship between soil depth reduction and maize yield

4.9 Final soil physical and chemical properties of soil under the tillage systems and fertility amendments

Exchangeable K and OC contents of final soil were not affected significantly by tillage and soil amendments at the end of the study (Table 4.11). There was a significant effect of tillage on available P and soil total N contents of the soil. However, soil total N content under the treatments was very low. Generally soil nutrient levels recorded at the end of the study were lower than those initially present in the soil (Table 4. 1) indicating decline over time. The soil pH also decreased over time to acidic condition.

Table 4.11: Final physical and chemical properties of the soil at 0-15 cm depth under tillage practices and soil amendments

Tillage practices	**pH**	**OC (%)**	**N (%)**	**P (mg/kg)**	**K (cmol/kg)**
Hoe-tillage	5.12	0.83	0.05	4.18	0.03
No-tillage	4.73	0.93	0.08	4.44	0.04
Plough-plant	5.04	0.90	0.08	4.22	0.03
Plough-harrow-plant	5.04	0.86	0.06	4.18	0.03
Bare	5.11	0.81	0.05	4.15	0.23
LSD(0.05)	0.89	NS	0.01	0.16	NS
CV (%)	8.70	7.20	12.30	5.20	10.70
Soil fertility amendment					
Control	5.04	0.84	0.06	4.19	0.03
% NPK	4.94	0.93	0.07	4.21	0.03
% PM	4.95	0.84	0.07	4.28	0.04
½ NPK+½ PM	5.01	0.89	0.06	4.35	0.03
LSD(0.05)	0.71	NS	0.01	0.31	NS
CV (%)	12.30	12.30	15.30	7.90	17.20

CHAPTER FIVE

5.0 Discussion

The following section includes a discussion regarding soil loss, runoff, gravimetric water content, volumetric water content, bulk density, porosity, aeration porosity, plant height and crop yields under the four tillage practices and amendments.

5.1 Tillage practices and gravimetric/soil moisture storage

Soil water content increased with depth similarly to those reported by Nargish (2012). Under all the tillage systems, soil moisture concentrated more in the sub-layers of the soil. This possibly, prevented evaporative loss through turbulent air movement over the soil surface. The relatively high moisture content of no tillage plots was due to the cumulative effect of organic mulch and the absence of tillage. Tillage exerts adverse effects on soil when improper tillage implements are used (Lio, 2006). Sarauskis *et al.* (2009) indicated that no-tillage increased rainwater infiltration and retained more water in the potential root zone compared with conventional tillage. Farhani *et al*. (1998) reported also that no-tillage conserved more surface residue, resulting in less evaporative losses.

5.2 Bulk density, porosity/aeration porosity

Relatively, higher bulk densities values were obtained under no-tillage compared to the other tillage systems. This could be due to the natural settling of the soil over time which often makes some amount of tillage necessary for crop growth. On the other hand, sandy loams in their natural state tend to have higher bulk density (Landon, 1991). Tillage systems however, altered bulk density and porosity of soils (Meek *et al.*, 1992). The increase in bulk density of the soil with no-tillage treatments has previously been also reported by Xu and Mermoud (2001). Tebrügge and

Düring (1999) reported bulk density of 1.2 to 1.35 Mg m^{-3} under inversion tillage and 1.4 to 1.5 Mg m^{-3} under no-tillage. Contrasting results have been reported for the effects of soil tillage systems on bulk density. Greater bulk density values under conventional tillage systems were reported when compared to no-tillage (Roscoe and Buurman 2003). The results of this study were consistent with the findings of Dam *et al.* (2005) that bulk density at 0-10 cm was 10% higher in no tillage (1.37 Mg m^{-3}) than in conventional tillage (1.23 Mg m^{-3}).

5.3 Soil Loss / runoff

The impact of tillage practices and soil amendments on soil loss and runoff were studied as the two factors account largely for land degradation in agriculture. In both seasons of study, no-tillage significantly reduced soil loss and runoff, and conserved more water than the other tillage practices. Vegetative cover accounted largely for the observed differences. This was further illustrated on the bare plot which recorded higher runoff and soil loss than the tilled plots. This corroborates with the findings of Sterk (1997) and Bu *et al.* (2008) who reported that soil erosion is severe when the land is bare.

Conservational tillage practices (e.g. no-tillage) rarely disturb the soil surface in comparison to conventional tillage practices. Mohammed and Umogbai (2014) reported that conservation tillage leaves a minimum of 30 % crop residues on the soil surface or at least 1,100 kg/ha of small grain residue. The higher surface residues and standing vegetation under no-tillage cushioned soil against the impact of raindrops and thereby protected the soil surface against the erosive forces of the raindrops and surface crust formation. The detachment of soil particles and surface sealing were therefore reduced. Consequently, soil infiltration was improved and hence, less runoff and soil loss.

Conventional tillage practices (as plough-harrow-plant) disturb soil structure, break soil aggregates and enhance their transport by runoff. In the short-term however, these practices reduce runoff and soil compaction, but this effect is lost as soon as it rains (Rao *et al.*, 1998). With loose soil on the surface and compaction below, a lot of the soil is washed away mainly, with the first rains (Kaihura *et al.*, 1998). Plough-harrow-plant thus accelerates soil erosion, cause compaction, reduce soil depth and loss of organic matter. Through soil compaction and erosion, particularly runoff, a major part of rainfall which is needed to fill the soil's moisture reservoir on croplands is lost. Sustainable tillage practices such as no-tillage and plough-plant should be encouraged in order to sustain crop growth and yield (Amegashie *et al.*, 2012). On the other hand by reducing soil disturbance, the cloddy surfaces and depression on the plough-plant field enhanced infiltration and reduced runoff and soil loss and thereby significantly recorded higher grain yield than the plough-harrow-plant.

One of the highlights of the study was that Hoe tillage recorded higher runoff and soil loss than plough-plant and plough-harrow-plant. Hoe tillage pulverizes the surface soil and increase the susceptibility of the topsoil to erosion. Comparing hoe tillage to plough-plant and plough-harrow-plant, the depressions formed under the two latter practices (as a result of ploughing) reduced the amount of runoff and soil loss. In this context, the plough-plant was more effective than the plough-harrow-plant as indicated above in reducing runoff and soil loss.

Higher runoff and soil loss recorded under the bare plot than the tilled plots was that the former had no cover to protect the soil against the erosive forces of raindrops and runoff. Runoff, detachment and transport of sediments were therefore higher.

The study indicated that, practices that increased land cover protected the soil surface against runoff and soil loss. The surface residues, vegetation and intensity of tillage practices were of critical importance to soil and water management and conservation. Tillage could be used to reduce runoff and soil loss, enhance infiltration and soil water storage. However, the order of preference for choosing the best tillage practice to reduce runoff and soil loss were no-tillage> plough-plant> plough-harrow-plant> hoe-tillage.

Another factor which could reduce runoff and soil loss but rarely considered is the use of soil amendments. Benneh *et al*. (1990) and Adu (1995) reported that application of soil amendments is of critical importance for increasing productivity of maize.

In comparison to the control (no amendments), the amount of runoff and soil loss were considerably reduced where the amendments were applied. Runoff under the control was 31.00 and 1.26 % greater than under the soil amendments, in the major and minor seasons respectively. Soil loss under 100% NPK, 100% PM and ½ NPK+ ½ PM were about 35.42, 16.63 and 19.01 % less than under the control.

The different amendments responded differently in reducing runoff and soil loss. The respective order of preference in choosing soil amendments to reduce runoff and soil loss are 100% NPK> 100% PM> ½ NPK+ ½ PM and NPK> ½ NPK+ ½ PM> 100% PM.

The significant differences recorded under the tillage x soil amendments further showed the importance of soil amendments in reducing both soil loss and runoff. The response of the soil amendments were however different under the different tillage practices.

To prevent runoff and soil loss, 100% NPK, 100% PM and a combined application of both could be used to amend the soil.

5.5 Plant logging and plant height

Logging significantly affected plant stand and yield. By maintaining crop residues on the surface, no-tillage system considerably reduced plant logging to the bearest minimum suggesting a good soil condition for root growth under the no tillage system. Martino and Shaykewich (1994) reported that no-tillage often results in greater soil strength.

No tillage gave highest values for plant height in both seasons at all stages of plant growth. This indicates that mechanized tillage did not favour maize growth. Agbede *et al.* (2008) and Memon *et al.* (2013) made similar observations. Although applications of NPK and PM were expected to produce significantly taller plants than the control due to availability of nutrients, similar plants heights were recorded on all plots. However, Akbar *et al. (*2002); Rasheed *et al. (*2004) and many other studies reported significant increases in plant height in response to fertilizer applications.

5.7 Grain yield/ biomass dry weight

Dry biomass and grain yield were higher under the no-tillage system than all other tillage systems. This may be due to the favourable effect of the no tillage system on soil moisture content and nutrient availability which could have improved nutrient and water uptake by the plants with consequent enhancement of dry matter production and grain yield.

The results obtained are consistent with the findings of Chan *et al.* (1996) that conservation tillage treatments recorded higher crop yield than conventional tillage treatments. Other studies also indicate that crops grown under no-tillage have yielded as similar as or better than those grown under conventional tillage (Mahli and

Nyborg, 1990; McAndrew, 1994). Memon *et al.* (2013) and Sial *et al.* (2007), however, stated that the best tillage practice for maize production is deep tillage followed by conventional tillage and no-tillage treatments. No-tillage can be particularly effective in enhancing crop yield during years of relatively low precipitation (Donovan and McAndrew, 2000).

Poultry manure in combination with NPK produced the highest total biomass (8261 kg ha $^{-1}$) and maize yield (1213 kg ha $^{-1}$) than sole applications of PM and NPK. This implies that integrated application of organic and inorganic fertilizer might be more desirable than either type of fertilizer alone. The increase in biomass and grain yield under combined PM and NPK was mainly due to availability of more nutrients from the two fertilizers for plant development. Vasanthi and Kumaraswamy (2000) reported that PM plus one-half the recommended inorganic fertilizer rate, yielded much greater amount of green fodder of corn than the full rate of NPK alone. In a study, Kornahanens (2006) observed higher grain yield under combined application of PM and NPK and attributed it to the complementary and synergistic effects of the fertilizers on maize growth and yield.

5.8. The relationships between rainfall, runoff and soil loss

The regression equation relating rainfall to soil loss and rainfall to runoff showed positive correlations. The positive correlation recorded between rainfall and soil loss indicated that more soil loss occurs when rainfall is high and vice versa.

Rainfall accounted for about 44 to 59 % and 63 to 72 % of variations in soil loss in the major and minor seasons respectively. The impact of rainfall on soil loss on the bare plots were even more, it accounted for about 77 % and 75 % of the variation observed in the major and minor seasons respectively. A unit increase in rainfall in the major season under no-tillage, plough-plant, plough-harrow-plant, hoe-tillage and bare plot resulted in a respective increase of soil loss by 7.89, 17.20, 16.25, 17.07 and 20.81 kg ha $^{-1}$. The corresponding values in the minor season were 0.89, 1.02, 1.04, and 1.06 kg ha $^{-1}$. The results further underscored the role played by plant cover in reducing the amount of runoff and soil loss.

Runoff accounted for about 55 % to 79 % and 59 % to 76 % of the variations observed in the runoff generation on the tilled plots in the major and minor seasons respectively. The respective values for the bare plots in the major and minor seasons were 79 % and 74 %. A unit increase in the rainfall increased runoff by 0.20, 0.37, 0.45, 0.48 and 0.52 mm runoff under no-tillage, plough-plant, plough-harrow-plant, hoe-tillage and bare plots respectively. Similar trend was observed under the minor season except for magnitude.

5.11 Relationship between soil loss, depth reduction and maize yield

Soil loss and maize yield were negatively correlated. Maize yield decreased with increasing soil loss. The R^2 showed soil loss to account for over 90 % and 50 % of the variations in the measured maize yield in the major season and minor seasons respectively. Maize yield decreased with increasing depth reduction. With regard to the relationship between soil depth reduction and maize yield, the R^2 values of 0.89 and 0.43 the major season and minor season respectively implies that depth reduction accounted for 89 % and 43 % of the variations in maize yield.

The loss of soil depth apart from its adverse impact on rooting depth reduced the water and nutrient storage capacities of the soil. Thus, the trend of the impact of the tillage practices on moisture storage was the inverse of that of soil depth reduction. The implication is that the greater the soil depth reduction, the less the moisture storage. The choice of tillage and soil management practices is therefore of prime importance, particularly in small holder rainfed agriculture, which depends solely on in-situ soil moisture storage from rainfall for crop growth (Adama, 2003). In this context, the preferred choice of tillage would be no-tillage> plough-plant> plough-harrow-plant> hoe-tillage.

CHAPTER SIX

6.0 Summary, conclusion and recommendations

6.1 Summary and conclusion

It was concluded from the study that no-tillage significantly reduced soil erosion (soil loss and runoff) and had positive effect on the grain and biomass yields of maize. Plough-plant tillage also produced reasonably good yields, maintained good soil condition and reduced plant logging. Grain yield recorded under all tillage practices were higher in the major season than in the minor season due to higher rainfall amounts received during the former.

The study has shown that maize yields from sole organic fertilizer or inorganic fertilizer application were significantly lower than yields from the combined application of organic and inorganic fertilizers. Soil moisture storage was higher under the no-tillage system than all the other tillage systems. Soil depth reduction was in the order of Hoe-tillage> plough-harrow-plant>plough-plant> no-tillage.
The results suggest that no tillage is the most effective practice for sustainable maize production under the specific field conditions. This is followed by plough-plant, plough-harrow-plant and then hoe-tillage.

6.2 Recommendations

No tillage and 1.5 t ha $^{-1}$ PM + 45-45-45 kg ha $^{-1}$ NPK have a most potential to sustain maize production. A few more experiments would, however, be required to ascertain their impacts. Similar studies on the subject should be conducted in the other agro-ecological zones of Ghana to confirm the findings of this study.

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APPENDIX

Appendix 1: Rainfall amount received in 2014

Month	Annual rainfall	Major season	Minor season
January	58.9		
February	46.2		
March	93.5		
April	128.6		
Mai	103.4	103.4	
June	270	270	
July	91.4	91.4	
August	74.2		
September	162.9		140.1
October	138.2		138.2
November	107.2		107.2
December	10.8		
Total	**1285.3**	**464.8**	**385.5**