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EFFECT OF TILLAGE PRACTICES ON SOIL FERTILITY: A CASE STUDY OF THE WEST MAMPRUSI DISTRICT OF NORTHERN REGION

BY

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THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY FOR PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MSC. DEGREE IN ENVIRONMENTAL SCIENCE

BY

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DECLARATION

I hereby declare that this submission is my own work towards the MSc. Degree and 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 of the Kwame Nkrumah University of Science and Technology or any other university, except where due acknowledgement has been made in the text.

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DEDICATION

This thesis is dedicated to my mother Catherine Tindjina of blessed memory who passed away during my MSc. work, my wife Comfort Baani and daughter Marciana Dezeinwe Tindjina.

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ABSTRACT

Food security is the basis for human survival. This however, depends on sustainable agriculture. Sustainability hinges on the efficient and judicious use of land and soil resources. This study conducted in the West Mamprusi district of the Northern Region of Ghana, sought to assess the effect of tillage practices on the fertility of the soil. The tillage practices assessed were 1. Tractor plough topsoil (TpT) 2. Tractor plough subsoil (TpS) 3. Bullock plough topsoil (BpT) 4. Bullock plough subsoil (BpS) 5. Hands hoeing topsoil (HpT) 6. Hands hoeing subsoil (HpS) 7. Zero tillage topsoil (ZpT) 8. Zero tillage subsoil (ZpS) 9. Fallow land topsoil (FlT) and 10. Fallow land subsoil. The study consisted of two components namely: a survey conducted in ten communities with twelve questionnaires in each community and soil nutrient analysis. Soil samples were collected in three locations at two depths (0-15cm as topsoil and 15-30cm for subsoil). ANOVA was used to analyse the results using the GENSTAT statistical package whilst treatment means were compared using Duncan's Multiple Range Test (DMRT) at P=0.05. Results from the survey indicated that 80 % of the respondents did not know of the effects of their tillage practices on soil fertility whilst 70.8 % of them had the opinion that use of agrochemicals had the greatest impact on soil fertility. 76.7 % of them indicated their awareness on organic farming or sustainable agriculture. On the maintenance of soil fertility, 44 %, 33 % and 23 % of them indicated avoidance of deforestation and use of fallow system, avoidance of extensive use of agrochemicals and use of crop residues and avoidance of farming near water bodies and the practice of crop rotation as the way forward for maintaining soil fertility respectively. There were significant differences ($P<0.05$) with regards to total exchangeable bases and effective cation exchange capacity between fallow land topsoil (FlT) and the rest of the tillage practices with the former showing superiority. Yield of maize per acre also indicated a significant difference between hands hoed and zero tillage with zero tillage being superior. However, bulk density, organic matter, total nitrogen and available phosphorus did not show any significant differences among and between the tillage practices ($P> 0.05$). The results indicated that the soil texture of the area was generally sandy loam to loamy sand with sand, silt and clay content ranging from 29.2-83.4 %, 4.6- 62.8 % and 4.0- 12.0 % respectively depicting the generally low magnitudes of soil fertility parameters. The manner in which soils are managed has a major impact on agricultural productivity. In order to be sustainable, development interventions must not only be economically sustainable but also socially acceptable and environmentally sound. Therefore, strategies to feed the ever growing population in the country have to seek a sustainable solution that would not mine the soil of its nutrients; and that would better address soil fertility management.

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LIST OF ACRONYMS

AEAs	Agricultural Extension Agents
ANOVA	Analysis of Variance
Ap	A profile
BIFAD	Board for International Food and Agricultural Development
BOA	Basic Ordering Agreement
BOD	Biological Oxygen Demand
BpS	Bullock plough Subsoil
BpT	Bullock plough Topsoil
CEC	Cation Exchange Capacity
CO_2	Carbon Dioxide
CSIR	Centre for Scientific and Industrial Research
CT	Conventional Tillage
DADU	District Agricultural Development Unit
Db	Bulk density
DMRT	Duncan's Multiple Range Test
EDTA	Ethylenediamine tetra-acetate
FlS	Fallow land Subsoil
FlT	Fallow land Topsoil
GAP	Good Agricultural Practices
GENSTAT	General Statistical Program
Hh	Hands hoe
HMP	Hexametaphosphate
HpS	Hand plough Subsoil
HpT	Hand plough Topsoil
IBSRAM	International Board for Soil Research and Management
LI	Legislative Instrument

MTNRE	Ministry of Tourism, Natural Resources and Environment
NGO	Nongovernmental organization
NRCS	Natural Resource Conservation Service
OC	Organic Carbon
OM	Organic Matter
RCBD	Randomized Complete Block Design
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SQ	Soil Quality
TEB	Total Exchangeable Bases
TpS	Tractor plough Subsoil
TpT	Tractor plough Topsoil
UNEP	United Nation Environmental Programme
USA	United States of America
USDA	United States Department of Agriculture
WMDA	West Mamprusi District Assembly
ZpS	Zero plough Subsoil
ZpT	Zero plough Topsoil
Zt	Zero tillage

CHAPTER ONE

INTRODUCTION

1.1 Environment

Global human population expansion and the associated increase in environmental degradation have led to the need for agricultural practices that promote food security and, at the same time, ensure that the quality of the environment does not deteriorate (Fowler and Rockstrom, 2001). Consequently, a large body of literature has accumulated on the sustainability of various agricultural practices and their long-term effects on soil and environmental quality (Fuentes *et al.*, 2009). Much of the published literature focused on the role of different tillage systems, with the emphasis placed on conservation tillage in commercial farming systems in developed countries. However, there is a deficit of similar research on the African continent, where agro-ecological and socio-economic conditions differ markedly from those experienced in developed countries (Fowler and Rockstrom, 2001).

The effects of tillage on soil physical, chemical and biological properties are a function of soil properties, environmental conditions and the type and intensity of the tillage system (Ishaq *et al.*, 2002). Ishaq *et al*. (2002) stated that the contradictory results of tillage effects on soil properties found in the literature "may be due to differences in crop species, soil properties, climatic characteristics and their complex interactions". Therefore, it is necessary to examine the long-term effects of tillage at different locations and under various environmental and soil conditions so that more accurate generalizations can be made regarding the conditions required for sustainable tillage systems (Ishaq *et al*., 2002).

1.2 **Soil and functions**

Soil is a three-dimensional, dynamic, natural body occurring on the surface of the earth that is a medium of plant growth and whose characteristics have resulted from the integrated effect of climate and living matter acting upon parent material, as modified by relief, over periods of time (Gupta, 2003). It is a mixture of minerals and organic constituents that are in solid, gaseous and aqueous state (Voroney, 2006).

Soil is used in agriculture, where it serves as the primary nutrient base for plants; however, as demonstrated by hydroponics, it is not essential for plant growth if the soil-contained nutrient could be dissolved in a solution. The types of soil used in agriculture (among other things, such as the purported level of moisture in the soil) vary with respect to the species of plants cultivated. Soil resources are critical to the environment, as well as to food and fibre production. Soil provides minerals and water to plants. Soil absorbs rain water and releases it later, thus preventing floods and drought. Soil cleans the water as it percolates. Soil is the habitat for many organisms: the major part known and unknown biodiversity in soil, in the form of invertebrates (earthworms, woodlice, millipedes, centipedes, snails, slugs, mites, springtails, enchytraeaids, nematodes, protest), bacteria, archaea, fungi and algae; and most organisms living above the ground have part of them (plants) or spend part of their life cycle (insects) belowground. Poor farming and grazing methods have degraded soils and release much of this sequestered carbon to the atmosphere. Restoring the World's soils could offset some of the huge increase in greenhouse gases causing global warming whilst improving crop yields and reducing water needs (Lal, 2004). Soils filters and purify water and affect its chemistry. Rain water and pooled water from ponds, lakes and rivers percolate through the soil horizons and upper rock strata; thus becoming ground water. Pests and pollutants, such as persistent organic pollutants (chlorinated pesticides, polychlorinated biphenyls), oils (hydrocarbons), heavy metals (lead, zinc, cadmium), and excess nutrients (nitrates, sulfates, phosphates) are filtered out by the soil (Kohne and Simunek, 2009).

1.3 Soil Fertility

Soil fertility is the quality that enables a soil to provide the proper nutrients, in the proper amounts and in the proper balance, for the growth of specified plants when other growth factors such as light, temperature, moisture and the physical condition of the soil are favourable. It is also said to be the ability of the soil to provide the plant with all its needs during the growing season. These definitions mean that depending on the specific growth requirements of a crop, a fertile soil for one crop may not necessarily be fertile for another. However, no matter the meaning attached to "soil fertility" the objective of increasing or conserving fertility is to obtain as large a yield as is economic, or as is possible, of the crops to be grown.

High fertility further implies an increase in the range of crops that can be grown. Strictly, a soil can only be fertile if it creates a favourable environment for root growth; and a soil can only be a suitable environment for plant roots if: (i) it is adequately drained and aerated; perhaps rice is the only exception of crops whose roots need only very little oxygen in the soil, as it appears to be supplied with oxygen through special tissues on the stem and root. (ii) if it's salt content and content of exchangeable sodium ions are low; and (iii) if its pH falls in a suitable range.

1.4 Soil quality and productivity

Soil quality (SQ) indices and indicators should be selected according to the soil functions of interest and the defined management goals for the system (Andrews *et al*. 2002). Agricultural productivity is the major recognized production function of soils. Soil quality affects crop productivity through its important functions such as nutrient cycling, physical stability and support, resistance and resilience and water relations. A good quality soil stores and cycles nutrients, and allows crops to grow and use nutrients (Andrews *et al.*, 2004)). In such soils, nutrients become available when the plants need them, reducing the chance of nutrients being lost from the root zone through leaching, from the surface by runoff or above the crop canopy by volatilization. This leads not only to optimum storage and utilization of nutrients, but also to reduced environmental risks. Among the important soil parameters related to nutrient cycling, soil pH, potentially mineralisable nitrogen and microbial biomass are often considered as indicators of soil quality (SQ) (Sparling, 1997). Soil erosion and runoff are among the detrimental factors in SQ management. Nutrients and soil organic matter (SOM) contained in the topsoil is often lost by erosion or washed out with runoff water. This does not only increase agricultural production cost due to the additional nutrient but also raises the risk of water pollution and leading to higher societal costs. Soil compaction is another major constraint with respect to agricultural soil quality. Compact soils restrict the movement of roots and nutrients in the soil, and hence reduce nutrient uptake and restrict air movement and gas exchange in the root zone, which leads to nutrient loss (UNDA-NRCS, 1997). Therefore, good soil aggregation is required for better water and nutrient movement through the soil. Higher aggregation in surface soils allows pore space for water infiltration and gas exchanges. Influenced by SOM and soil biological activities, soil aggregate stability and bulk density are often considered as indicators for soil physical stability and support (Arshad *et al.*, 1996).

When nutrients are applied to the soil surface, water is required to move them into the root zone (UNDA-NRCS, 1997). This requires sufficient infiltration capacity of the soil. The movement of nutrients improves their availability to the plants and reduces their susceptibility to runoff and volatilization. As soil moisture is an important attribute determining soil productivity function, plant available water capacity, is often considered as indicator of water relations (Andrews *et al*., 2002).

1.5 Rationale for Soil Fertility Concerns

The increased awareness of soil as a critically important component of the earth's biogeosphere has stimulated interest in the concept of and assessment of soil quality (Glanz, 1995). Demand on soil resources for enhancing food security, improving water quality, disposing wastes and mitigating climate changes has become important in response to growing population. This increased demand has intensified anthropogenic activities and amplified pressure of degradation. Although the threats of land degradation are wide spread, it is more intensive in the poorer regions, where the land users entirely depend on the inherent capacity of the land for their basic needs.

A soil fertility test evaluates the nutrient-supplying power of a soil. The results of the test are used to predict if, or how much fertilizer is required for optimum plant growth. Soil fertility test becomes necessary when human activities on the soil renders the soil infertile resulting in low yields due to the poor growth and development of crop plants (Wolkowski, 1996).

Bjonnes (1996) indicated that soil depletion occurs when the components which contribute to fertility are removed and not replaced; and the conditions which support soil fertility are not maintained. This leads to poor yields. In agriculture, depletion can be due to excessively intense cultivation and inadequate soil management. One of the most wide spread occurrences of soil depletion as at 2008 in the tropical zone is where nutrient content of soil is low. The combined effects of growing population densities, large scale industrial logging, slash-and-burn agriculture, land clearing practices and other factors have in some places depleted soil through rapid and almost total nutrients removal (Bjonnes, 1996). Bjonnes (1996) added that topsoil depletion is when the nutrient rich organic topsoil that takes hundreds to thousands of years to build up under natural conditions is eroded or depleted of its original organic matter.

1.6 Sustainable Agriculture

Papendick and Parr (1990) stated that for a farm to be sustainable, it must produce adequate amount of high quality food, protect its resources and be both environmentally safe and profitable instead of depending on purchased materials such as fertilizers and that a sustainable farm relies as much as possible on the beneficial natural processes and renewable resources drawn from the farm itself. Allen *et al.* (1991) defined sustainable agriculture as one that equitably balances concerns of environmental soundness, economic viability and social justice among all the sectors of the society. Sustainable agriculture simply means farming with wisdom or farming without causing any serious damage to the soil, environment, plant, water bodies, humans and animals. Sustainable farming involves the profitable production and marketing of high quality products. It is the use of best management practice, which enhances the quality of the resource, and also seeks to protect natural ecosystems. With sustainable farming, a balance between the interests of profitability, maintaining and improvement of the environment in which the farming takes place, must be made. It is utmost important that the farmer not only makes a comfortable income for himself, but to also maintain the land and its conditions to a state with which it can sustain and support future generations (www.sciencedirect.com). (BIFAD, 1988) referred to sustainable agriculture as the successful management of resources for agriculture to satisfy changing human needs, whilst maintaining or enhancing the natural resource base and avoiding environmental degradation; the ability of an agricultural system to maintain production over time in the face of social and economic pressures; and one that should conserve and protect natural resources and allow for long-term economic growth by managing all exploited resources for sustainable yields. (BOA/NRC, 1989) considered sustainable agriculture as a system synonymous with alternative agriculture, which is any system of food or fibre production that systematically pursues the following goals: more thorough incorporation of natural processes such as nutrient cycles, nitrogen fixation, and pest-predator relationships into agricultural production processes; reduction in the use of off-farm inputs with the greatest potential to harm the environment or the health of farmers and consumers; greater productive use of the biological and genetic potential of plants and animal species; improvement of the match between cropping patterns and the productive potential and physical limitations of agriculture lands to ensure long-term sustainability of current production levels and profitable and efficient production with emphasis on improved farm management and conservation of soil, water, energy and biological resources.

1.7 Main Objective

The objective of this research therefore, was to assess the effect of tillage practices on soil fertility.

1.8 Specific Objectives

The specific objectives were to:

- assess tillage methods employed by farmers in the district
- determine soil physical properties of the soil sampled
- determine soil chemical properties of the soil sampled
- evaluate nutrient contents of the soil sampled

1.9 Rationale for the Study

Agricultural tillage practices have adverse effects on soil fertility. However, farmers appear to be ignorant on their farming activities on the fertility of the soil as well as the environment. Agriculture is the basis for human survival and therefore, the need to ensure the provision of safe food stuffs. Soil is the very resource on which agriculture is based and therefore, needs to be protected so as to enable food production to be continuous and beneficial in order to ensure food security for the ever growing population.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tillage and Purpose

Tillage is defined as mechanical manipulation of soil to provide a favourable environment for good germination of seeds and crop growth, to control the weeds, maintain infiltration capacity and soil aeration. A well planned tillage practice provides a favourable environment, suitable for better seed germination and effective plant growth. In addition, it also protects and maintains a strong soil structure to reduce soil erosion (Wolkowski, 1996).

Tillage aims to create a soil environment favourable to plant growth (Klute 1982). Definitions of tillage vary. 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 includes all operations of seed bed preparation that optimize soil and environmental conditions for seed germination, seedling establishment and crop growth (Lal, 1983). Tillage is defined as the soil related action necessary for crop production (Boone, 1988). The overall goal of tillage is to increase crop production whilst conserving resources (soil and water) and protecting the environment (IBSRAM 1990). The benefits of tillage could be summed up as for seed bed preparation, weed control, evaporation suppression and water infiltration enhancement and erosion control. Appropriate tillage practices are those that avoid the degradation of soil properties but maintain crop yields as well as ecosystem (Greenland, 1981).

Soil manipulation can change fertility status markedly and the changes may be manifested in good or poor performance of crops (Ohiri and Ezumah, 1990).

The basis of conventional tillage is the annual ploughing or tilling of the soil, but this is usually supplemented with a number of other practices including the removal or burning of soil residues, land leveling, harrowing, fertilizer application and incorporation, inter-row cultivation (Kaihura *et al*., 1998)

All these practices cause soil disturbances, compaction and deterioration. Consequently, in many areas, conventional agriculture has led to a decline in crop yields and profitability.

Ploughing causes the rapid break down of organic matter. The soil collapses and compacts, reducing erosion and a number of soil organisms. The topsoil becomes susceptible to erosion and water runoff, so that after heavy rainfalls a great deal of soil is lost as little water is retained, leading to shallow and infertile soils which are no longer able to produce good yields. The cost of production also increases as the farmer needs to apply more fertilizer and use fuel to plough his or her land.

Conservation agriculture is one possible answer to deterioration caused by conventional farming practices. It encourages soil protection and care through reduced tillage practices and the maintenance of surface residues. This minimizes soil disturbance, encourages build up of organic material, preserve the soil structure and conserves soil water. Conservation agriculture is radically different from conventional farming practices. Therefore, if farmers are to successfully implement the system, a change to their entire mindset is necessary.

Under conservation agriculture, a number of tillage operations is reduced or entirely eliminated and direct sowing is used. Cultivation of green manure (e.g. legumes) is encouraged to enrich the soil. Instead of hoeing to remove weeds, cover crops and residues help to smother emerging weeds. After harvesting, crop residues are left on the land. Crop rotation and intercropping are encouraged in order to break-up pest cycles and to avoid soil exhaustion from continuous monocropping (Uri, 1998).

2.2. Types of Tillage Practices

2.2.1. Factors Affecting the Choice of Tillage Practices

Tillage is a labour-intensive activity in low-resource agriculture practiced by small land-holders, and a capital and energy-intensive activity in large-scale mechanized farming (Lal 1991). For any given location, the choice of a tillage practice will depend on one or more of the following factors: soil factors such as relief, erodibility, erosivity, rooting depth, texture, structure, organic matter content, mineralogy; crop factors such as growing duration, rooting characteristics, water requirement, seed; climatic factors such as rainfall amount and distribution, water balance, length of growing season, temperature; socio-economic factors such as farm size, availability of a source of power, family structure and composition, labour, access to cash and credit facilities and government policies, objectives and priorities (Unger 1984a).

According to Unger *et el*., (1988) conservation tillage systems to protect the soil and water reserves often have limited appeal to producers unless they offer economic advantages. Economic factors contributing to interest in conservation tillage include:

i. high costs of fuel, labour, tractors and other equipment;

ii. high equipment inventories and maintenance costs;

iii. ability to use land at risk of erosion for more intensive crop production (rather than for pastures or in long-term rotation);

iv. the opportunities offered for more intensive cropping, avoiding long fallow periods, because greater water conservation; and in many instances, higher crop yields.

2.2.2. Conventional Tillage

These involve the mechanical soil manipulation of an entire field, by ploughing followed by one or more harrowings. The degree of soil disturbance depends on the type of implement used, the number of passes, soil and intended crop type. It refers to the cultivation of the soil using ploughs, harrows, bullocks and other farm tools or mechanical implements to prepare the field for crop production. In the humid and sub-humid regions of West Africa, 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 (Morgan and Pugh 1969). To facilitate seedbed preparation and planting, forest undergrowth or grass is cleared with a cutlass and trees and shrubs left, but pruned. The cut biomass and residues are disposed of by burning *in situ*. This type of clearing is non-exhaustive, leaving both appreciable cover on the soil, and the root system which gives the topsoil structural stability for one or two years (Aina *et al*., 1991).

The most widespread method of soil cultivation practices throughout the world is mouldboard ploughing. The steel share or blade of the plough is shaped so that when it is drawn through the soil behind a tractor it penetrates to a fairly constant depth and overturns the surface layer to one side, thus leaving an initially empty V-shaped furrow. The next pass of the plough is displaced a short distance (20-30cm) to the other side, so that the first furrows are filled with overturned soil from the second furrow. This process is continued until the whole field has been overturned and disturbed to a constant depth, usually 20-25cm with modern equipment (Fullen and Catt, 2004). Land degradation is a growing problem in Tanzania because of increased human activity and land demand as a result of the growing population. Deforestation, over-grazing and inappropriate tillage practices are contributing heavily to land degradation. It has been observed that the rate of soil losses in some parts of the country have increased from 1.4 tons/ha/year in 1960 to 224 tons/ha/year in 1980 (MTNRE, 1994). With the increased population pressure, the fallow periods, which were commonly practiced, have become shorter for the soils to recover perpetuating the "soil mining" of nutrients. The replenishment of nutrients is low because of inadequate application of manure and inorganic fertilizers. This leads to a further decline in soil fertility, which is manifested in declined crop yields. Conventional tillage, which is most commonly practiced in the country, involves the use of hand hoes, ox drawn mouldboard ploughs, tractor drawn disc ploughs and harrows combined with straw collection and burning during land preparation. During the operation the soils are cut, inverted and pulverized burying most of the residues underneath. The practice frequently causes soil compaction, affects soil physical properties, provokes biological degradation and results in declined crop yields. With fine dust on the surface and compaction below, a lot of soil is washed away with the first rains. Soil losses of up to 30 tons/ha have been reported in Kilimanjaro region in conventional flat cultivated fields at a slope of 5% (Kaihura *et al*., 1998). The costs for land preparation are increasing every year due to the rising costs of fuel and tractor spare parts.

The merits of this tillage practice among others include:

- Powerful tractors can pull ploughs with multiple shares, so that four to eight furrows may be drawn with a single pass. Weeds and residues of the previous crop are almost completely buried by this procedure and usually decompose more rapidly than if left on the soil surface (Fullen and Catt, 2004).

- Ploughing in the form of secondary cultivation treatments crudely sort aggregates, with the coarsest at the surface. Sorting of this type occurs mainly on dry soils and results from small aggregates falling through the gaps between larger aggregates when they are disturbed. It is known as kinetic filtering, kinetic sieving or interparticle percolation. It also bring larger stones to the surface, which can have the effect of increasing infiltration rates and decreasing evaporation and erosion of finer soil particles (Oostwoud Wijdenes and Poesen, 1999).

The demerits of this tillage practice however, are:

- Repeated annual or more frequent ploughing leads to a homogenized uppermost soil layer (the Ap horizon), which has a uniform thickness and a sharp boundary over less organic horizons beneath. At the base of the Ap horizon a thin layer smeared and compacted soil (the plough sole or plough pan) is often formed (Francis *et al*., 1987). This may limit root penetration or periodically create anaerobic conditions within the Ap horizon, which can prevent germination (Richard and Guérif, 1988).
- Increased energy costs of deep ploughing can outweigh the economic benefits of increased yields. Ploughing to depths >25cm usually leads to a decrease in the organic matter content of the Ap horizon because of dilution with subsoil material containing very little organic matter. This decreases the chemical fertility of the soil and weakens the soil structure, so that water or wind erosion may be increased and compaction may occur more easily (Fullen and Catt, 2004), destroys the soil cover and its structure.

- Ploughing exposes the soil surface to agents of erosion such as wind, rain and as such enhances soil erosion, results in high moisture loss, disrupts the life cycle of beneficial soil organisms and needs more labour cost for soil preparation (Broller *et al.*, 2004).

2.2.3. Conservation Tillage

There are several crop cultivation treatments that involve planting seeds directly into the previous crop residues. Currently, these systems are known as crop residue management systems, but they are also referred to as no-tillage, minimum cultivation, conservation tillage or direct drilling. The range of terminology is partly a reflection of the diversity of systems in use. In essence, the residues from the previous crop are left on the soil surface, to stimulate the protective effects of vegetation. Fundamentally, this is a form of mulching. Then the next series of crops are planted and grow into the residue, and the new crops eventually provide the vegetative protective cover. These techniques have become popular over recent decades, especially in North America (Uri, 1998).

Conservation tillage, zero or minimum tillage, is one of the practices that has proved to combat soil degradation efficiently. While millions of hectares of farm land are already under zero tillage in Latin America, in Africa, conservation tillage is restricted mainly to larger estates. There are, however, enough examples demonstrating that conservation tillage can be practiced successfully by small holder farmers too. Yet much work is needed to demonstrate that the technology works in order to change the mindset of farmers who for many years were taught or learned from their parents that it is necessary to plough and maintain a weed free field for better crop production. This is planting or sowing in the previous crop's residues that are purposely left on the surface. In conservation tillage the crop residues are left as mulch on the soil surface to limit evaporation and runoff, thereby conserving soil water. The seedlings also have to compete with weeds, unless these are killed with a suitable selective herbicide. Various methods are employed in conservation tillage practices. Some of these include:

Zero Tillage (no-till, minimum tillage or direct sowing). This is a system where the soil is not disturbed between harvesting one crop and planting the next. It is a crop production where the soil is not traditionally tilled or cultivated although sticks or other planting equipments are used to make the openings for seeds. It involves planting seed by pushing it a few centimeters directly into the soil that has not previously been disturbed at all by ploughing. 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 upper most 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.

Ridge Tillage which is a specific form of no-till 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 the planting time. The seeds are sown along the ridges. Sticks are or other farm tools are used to make the openings for seeds.

Mulch Tillage (Stubble 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.

Merits of this system of tillage practice include:

- It is quicker, so that larger areas of land can be sown at the optimum time, sometimes within a few hours of harvesting the previous crop, to ensure early crop establishment and maximize the length of growth period (Christian and Ball, 1994).
- The natural structure of the surface soil is retained almost intact, so that percolation by preferential flow through the macrospores created by old root and faunal (e.g., earthworm) channels is better than where the continuity of these features is destroyed by ploughing (Petersen *et al.*, 2001).
- Crop residues left on the soil surface increase earthworm activity (Mele and Carter, 1999), in turn increasing infiltration rates and thus decreasing runoff and erosion (Edwards *et al*., 1988). The residues also prevent the formation of surface crusts and insulate surface soil from temperature extremes at times when there is no crop canopy. Consequently, sandy and other low grade soils can be used more effectively and with less erosion risk (Quinton *et al.*, 2001), even on steeper slopes. Earthworms help incorporate crop residues, and in time their casts generate a well- structured surface layer.
- The overall effects are usually an improvement in soil quality and decrease in pollution of surface waters by erosion. Also, in many situations, zero, minimum and conservation tillage techniques have increased rather than decreased crop yields, often because of better germination and crop establishment (Christian and Bacon, 1990). Even where yields are less than with conventional tillage, the difference is usually small, and the savings in machinery, labour and fuel costs increase profit margins compared with conventional tillage.
- Initially there is less oxidation of soil organic matter because there is decreased contact with the atmosphere, and consequently there is less degradation of soil structure, less

leaching of nitrates released by mineralization (Power and Peterson, 1998) and less leaching of metal ions released by soil acidification. After several years of organic matter may become concentrated in a thin (often <2.5cm) surface layer, because it is not incorporated more deeply by cultivation, and the rate of mineralization may then increase, so that in the long term less fertilizer N may be required (Ismail *et al.*, 1994).

When these systems were extensively developed, particularly in the 1970s and 1980s, many considered them as the panacea to many soil management problems, especially soil conservation. However, there are various negative aspects of these systems. These include:

- The decomposition (mineralization) of crop residues is slower on the soil surface, often approximately 60 per cent of that buried residues (Douglas *et al.*, 1980), so that the turnover of nutrients is slower, residues incorporated into the soil are exposed to a large microbial population and mineralized quicker. Decomposition of surface residues is most rapid in climates where warm and preferably moist conditions prevail for most of the year.
- Initial root development can be delayed because soil close to the soil surface (within about 25 cm depths) may be more compact than frequent ploughing (Schjønning and Rasmussen, 2000).
- One of the aims of ploughing is to bury weeds, to present a clean weed-free surface for subsequent cultivation. The lack of tillage can allow weed infestation and this is particularly a problem with grasses such as blackgrass (*Alopecurus myosuroides*) and sterile brome (*Bromus commutatus*), and volunteers (self-sown plants of previous crops) (Christian and Ball, 1994). Control often involves increased used of expensive herbicides and so these systems are not necessarily compatible with organic farming.

- There is greater loss of N by denitrification (Rice and Smith, 1982) or volatilization of urea-based fertilizers (Dick *et al.*, 1991) under zero tillage. It needs patience and waits a longer time to have an excellent soil (Broller *et al.*, 2004).

2.3 Effects of Tillage Practices on Soil Properties

Because of increasing recognition that soils can profoundly influence crop production, human and animal health and many aspects of the environment, there is at present growing national and international pressure to establish standards of soil quality, sometimes alternatively termed soil health. This is strongly advocated by policy makers as well as environmental pressure groups and members of the public. However, most scientists recognize the considerable difficulties involved in deciding standards applicable to all soil types and all properties that affect fertility and the environment. So, although some proposals have been made, principally for standardization of soil description, sampling and analytical methods (Hortensius and Nortcliff, 1991), no standards have yet been agreed for national or international use.

Soil quality, also commonly referred to as soil health, is linked to human health and environmental sustainability. As such, there is a need to evaluate the effect of agroecosystems, and the practices employed, on soil quality (Jake and Papendick, 1994). Soil quality is difficult to define and quantify as it is a function of physical, chemical and biological properties of the soil (Fuentes *et al*., 2009), which are influenced by environmental conditions and soil management (So *et al*., 2009). Govaerts *et al*. (2008) define a healthy soil, which is able to support a sustainable production system, as "…the continued capacity of the soil to sustain biological productivity, maintain quality of air and water environments and promote plant, animal and human health".

Tillage alters the physical, chemical and biological properties of soil ecosystems (Doran, 1980) and thus it is an agricultural practice of particular interest in its effect on soil quality. The increasing cost of fossil fuel, loss of topsoil due to erosion, and increasing environmental pollution has led to the need for agricultural management to be more focused on less intensive and more sustainable soil-cultivation practices (Köller, 2003). The motivating factors encouraging farmers to convert from conventional tillage to conservation tillage include savings in time and fuel, reduced machinery and labour costs, and erosion mitigation (Beauchamp and Hume, 1997). Further benefits associated with conservation tillage are improved soil physical properties and consequent increases in crop productivity. Generally, the increased amount of crop residues remaining on the surface under conservation tillage improves the soil's physical and biological characteristics which results in increased soil fertility and soil quality (Andrade *et al*., 2003).

Tillage affects soil physical, chemical and biological properties. Research results have been widely reported on the effects of tillage on soil aggregation, temperature, water infiltration and retention as the main physical parameters affected. The magnitude of the changes depends on soil types as well as soil composition. Changes in chemical properties are dependent mainly on the organic matter content of the soils. Tillage affects aeration and thus the rate of organic matter decomposition. Biological activities in the soil are vital to soil productivity through the activities of earthworms, termites and the many other living creatures in the soil. These influence water infiltration rates by their burrowing in the soil and their mucilage promotes soil aggregation.

Tillage effects on soils are closely related to the management of crop residues in and on the surface of the soil. Unger *et al*. (1991) point out that the two practices with major impact on soil conservation are crop residue management and tillage. The traditional ploughing-in of crop residues is now giving way to surface soil residue management, which is more related to soil and water conservation, particularly in the semi-arid tropics.

Farmers have a real challenge with managing the physical and the biological health of the soil because traditionally tillage is a very integral part of the cropping system. Yet we now know that tillage also has a strong negative impact on the health of the soil and certainly if tillage is repeated year after year for many decades we see tremendous degradation of the soils. So we need to focus on finding alternatives tillage systems to build up those soils again and make them productive for our crops.

Tillage affects soil health in a complex way; in the short term tillage provides benefits by loosening the soil and allowing for water infiltration and oxygen to enter into it. The long term however, repeated tillage oxidizes organic matter that's critical for soil aggregation and structure, and so what we see after decades of repeated intensive tillage is that the soil degrades and become dense and compacted (Gruninger, 2007)

The moldboard plow has been used for centuries to invert the soil. It's a very effective tillage tool, but it also breaks up soil aggregates, oxidizes the organic matter which is critical to good soil aggregation. It also causes plow pans that reduces root proliferation into the subsoil.

The rotovator is a tool that does an excellent job of creating a seedbed and has been used in vegetable systems for that reason. The concern about the rotovator is that, much like the moldboard plough is that it's a very intensive tillage tool and in the long run it causes the destruction of soil aggregates.

The disc harrow in a way performs less intensive tillage which is good, but it has one particular problem, that it causes a lot of pressure at the bottom of the discs especially when it's offset at a wide angle and this causes some compaction which results in what we call a disc pan.

To build healthy soils we need to use good management practices and I look at it as a balance sheet. Tillage and intensive mono-crop production are practices that reduce the health of the soil - they degrade the soil. Other practices, like cover cropping, good rotation especially those including sods and legumes, and the addition of organic matter like manure and compost help build the soil. In general, what a farmer wants to achieve is a good balance between those practices. One of the interesting things we've found is that these soil-building practices can also mutually reinforce each other. For example combining reduced tillage or no tillage with cover cropping, enhances the benefits of both (Gruninger, 2007).

In Nigeria, scientists at the International Institute of Tropical Agriculture, Ibadan, started research on no-tillage or mulch-tillage systems in 1970 (Rockwood and Lal 1974). Other scientists working in national research institutes and universities in Nigeria also started studies on a range of soils in the 1970s to compare the effects of different tillage methods on soil properties, crop growth and yield (Aina 1979).

In the USA, Unger *et al*. (1988) report that except for stubble mulch tillage, there was limited interest in crop production systems involving surface residues until the late 1960s or early 1970s when interest became widespread. Several more recent studies have shown that no-tillage systems with crop residue mulch can:

a. maintain the productivity of upland soils by reducing erosion (Mensah-Bonsu and Obeng 1979).
b. improve water-retention capacity (Hulugalle *et al*. 1990).
c. improve water use efficiency (Osuji 1984 and

increase nutrient use efficiency (Hulugalle *et al*. 1985). The no-till system seems to have a broad application in humid and sub-humid regions, for which 4-6 tons ha^{-1} of residue mulch appears optimal (Aina *et al*. 1991).

2.3.1 Effect of Tillage on Soil Physical Properties

Repeated annual ploughing or more frequent ploughing under conventional tillage leads to a homogenized upper most soil layer (the Ap horizon), which has a uniform thickness and a sharp boundary over less organic horizons beneath. At the base of the Ap horizon, a thin layer of smeared and compacted soil (the plough sole or plough pan) is often formed (Francis *et. al*., 1987). This may limit root penetration or periodically create anaerobic conditions within the Ap horizon, which can prevent germination (Richard and Guerif, 1988). Compaction is becoming a serious problem in agriculture (Soane and Ouwerkerk, 1995), mainly because of the increasing weight of farm machinery and decrease in aggregate strength resulting from the slow loss of organic matter under a regime of repeated soil cultivation for arable crop. It occurs when the external stress or force applied at the soil surface exceeds the strength of bonds at points of contact between individual particles or soil aggregates, so that compression and shearing lead to a decrease in the size of voids and thus to an increase in bulk density (Db). As the applied stress increases, Db reaches a maximum because the soil particles cannot be packed more closely without being fractured.

Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.*, 2006). Tillage method affects the sustainable use of soil resources through its influence on soil properties (Hammel 1989). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1993). Use of excessive and unnecessary tillage operations is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation and no-tillage methods for the purpose of controlling erosion process (Iqbal *et al.*, 2005).

Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil intact (Rashidi and Keshavarzpour, 2007). This difference results in a change of number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water and agricultural chemicals. This in turn controls erosion, runoff and crop performance (Khan *et al.*, 2001).

On the other hand, conservation tillage methods often result in decreased pore space (Hill, 1990), increased soil strength (Bauder *et al.*, 1981) and stable aggregates (Horne *et al.*, 1992). The pore network in conservationally tilled soil is usually more continues because of earthworms, root channels and vertical cracks (Cannel, 1985). Therefore, conservation tillage may reduce disruption of continues pores. Whereas, conventional tillage decreases soil penetration resistance and soil bulk density (Khan *et al.,* 1999). This also improves porosity and water holding capacity of the soil. Continuity of pore network is also interrupted by conventional tillage, which increases the tortuousity of soil. This all leads to a favorable environment for crop growth and nutrient (Khan *et al.,* 2001).

Bulk Density (Db)

Bulk density is the weight of soil for a given volume. It is used to measure compaction. In general, the greater the density, the less pore space for water movement, root growth and penetration as well as seedling germination (www.google.com-04/10/2010 at 10am). Soil bulk density, like all density measurements, is an expression of the mass to volume relationship for a given material. Soil bulk density measures total soil volume. Thus, bulk density takes into account solid space as well as pore space. Soils that are loose, porous, or well-aggregated will have lower bulk densities than soils that are compacted or non aggregated. This is because pore space (or air) weighs less than solid space (soil particles). Sandy soils have less total pore than clayey soils, so generally they have higher bulk densities. Bulk densities of sandy soils vary between 1.2 to 1.8 Mg m^{-3}. Fine-textured soils, such as Clays, silty clays, or clay loams, have bulk densities between 1.0 and 1.6 Mg m^{-3} (White, 1997).

Farmers often speak of 'heavy 'and 'light soils' in relation to the ease of tillage. 'Heavy' soils are clayed and difficult to till, whiles 'light' soils are sandy and easy to till. These terms are misnomers in the technical sense because sandy soils are heavier per unit volume than clayed soils. Remember that sandy soils have less pore space than clayed soils, so in a given volume of both soils, the sandy soil has less air (more solid soil particles) and is therefore heavier. The term 'heavy' and 'light' actually refer to other physical properties of soil, such as plasticity, cohesion, adhesion etc. which determine the soil ease of tillage.

Bulk is an indirect measure of pore space and is affected primarily by texture and structure. As aggregation and clay content increase, bulk density decreases. Tillage operations do not affect texture, but they do alter structure (soil particle aggregation). Primary tillage operations, such as ploughing, generally decrease bulk density and increase pore space, which is beneficial. Secondary tillage (cultivation) generally increases bulk density and decreases pore space. The compaction resulting from cultivation can be detrimental to plant growth. Cropped soils generally have higher bulk density than uncropped soils. The movement of machinery over the field forces solid particles into spaces once occupied by water or air, resulting in less pore space and increased bulk density.

Reports have indicated contrasting results as to the effect of tillage on bulk density. Blevins *et al.* (1983a) reported that tillage had no effect on bulk density after a 10 year period of tillage treatments on a medium textured soil. However, other studies have reported a drastic increase in bulk density with no-till compared to mould board ploughing of clay loam soil (Griffith *et al.*, 1977). Blevins and *et al.* (1983b) found similar bulk density values with conventional and no-till system and smaller bulk density with chisel tillage on poorly drained soil.

Tillage influences the total porosity and pore size distribution of the soil by affecting the soil structure. This results in changes in soil hydraulic properties and soil strength, both of which are important determinants of soil quality. Due to its relationship with soil porosity, bulk density (Db) is a useful measure for assessing tillage effects on the structural characteristics of the soil (Simmons and Coleman, 2008) and the consequent effects on the water and aeration status of the soil (Linn and Doran, 1984), hydraulic conductivity, infiltration rate, water retention characteristics, and soil strength (Simmons and Coleman, 2008).

Soil manipulation can change fertility status markedly and the changes may be manifested in good or poor performance of crops (Ohiri and Ezumah, 1990). In addition, tillage operations loosen, granulate, crush or compact soil structure, changing soil properties such as bulk density, pore size distribution and composition of the soil atmosphere that affect plant growth.

Tillage loosens the soil structure and causes an immediate increase in the percentage of macropores, resulting in a lower ρb and greater total porosity (So *et al*., 2009) which can benefit seedling establishment and crop growth (Sturz *et al*., 1997). Generally, converting from a CT system to a conservation tillage system results in a higher ρb and a lower total porosity (Johnson-Maynard *et al*., 2007) as macropores are not created as is the case during ploughing.

Particle Size Distribution

Particle size analysis is aimed at determining the soil texture which refers to the relative particle distribution in a given soil sample. The degree of aeration, moisture content and depth of penetration of the soil are directly related to other physical properties of soil such as structure and consistency. These properties also determine the productive capacity of soil. Tillage brings about compaction which has effect on soil particles.

The effect of pressure applied at the soil surface, for example by a tractor tyre, decrease downwards in the soil. The downward attenuation rate is influenced by the same range of factors as those determining surface strength such as particle size distribution (Ball *et al*., 1997).

Soil is composed of aggregates surrounded by large spores. Aggregates are high-bulk density soil units containing small spores that enhance water retention and nutrient storage. The relatively large spore spaces between aggregates promote rapid water infiltration, water drainage, air exchange and root growth. However, during compaction, aggregates are pressed closer together, resulting in a loss of large pores due to ploughing. If compaction forces are sufficiently large, small pores dominate in compacted soil, resulting in slow water infiltration, slow water drainage, reduced aeration and increased resistance to plant root growth (Lal and Pierce, 1991).

2.3.2 Effect of Tillage on Soil Chemical Properties

Organic Carbon

Organic carbon (O.C.) content in the soil is directly proportional to the organic matter content. Organic matter (O.M.) is made up of partially decayed and partially synthesized plant and animal residues. It is continually being broken down by soil microorganisms. It must, therefore, be replenished by the addition of plant residues to the soil.

Soil organic matter plays a fundamental role in agriculture land use, largely through its influence on water content, nutrient status and structural stability (Bell, 1993). The humus fraction in particular has a very high water-holding capacity and can retain up to four times its own dry weight of water; about 50 per cent of this is likely to be plant available. In fact, the presence of 5 per cent humus will increase the plant available water content of a sandy loam by more than 50 per cent and that of clay loam by about 30 per cent above levels in comparable organic free soils (Simpson, 1983). In addition to its water retention properties, O.M. is often added to soils as mulch to reduce water losses by evaporation. O.M. is also an important source of essential plant nutrients, particularly nitrogen. The humus fraction in particular has a very high Cation Exchange Capacity (C.E.C.) and therefore able to retain nutrients such as base cations which are available for plant uptake.

An important effect of ploughing and secondary cultivation is to incorporate organic manures and crop residues (Staricka *et al.*, 1991). Most implements result in a clustered arrangement of residues rather than a homogenous distribution, and chopping crop residues after harvest and before ploughing often improve the distribution. It also accelerates the decomposition of residues and thus the recycling of nutrients. Natural breakdown of aggregates by secondary cultivations exposes organic matter that would otherwise be protected within clods or undisturbed soil (Balesdent *et al.*, 2000). This also accelerates release of nutrients by microbial activity.

Incorporation of fresh organic materials by ploughing can also improve the abundance and strength of small aggregates (Watts *et al.*, 2001). As it also increases microbial respiration, this structural improvement seems to depend at least partly on microbial activity, and increases in temperature.

The increased release of nutrients from soil organic matter by tillage may improve crop growth. However, it can also present environmental problems if the mineralization occurs when crops have not germinated or are growing very slowly and therefore require little or no nutrients, as in mid-and high-latitude regions. In such circumstances, zero or minimum tillage techniques can initially decrease losses of nitrate compared with ploughing, because organic matter is stored in the soil rather than mineralized. However, ploughing up soils that have been under zero or minimum tillage for several years can lead to large increases in losses of nitrates, as the additional, fresh and therefore less stable organic matter is rapidly mineralized (Catt *et al.,* 2000).

Organic matter content that has declined for decades by tillage practices affects soil property and fertility level and induces crop yield decline (Zougmore and Hosikawa, 2006).The organic content of soil varies drastically in response to differences in land use. Contents are often lowest in soils under intensive arable cultivation, as relatively little organic matter is returned to the soil after harvest. Compaction which occurs as a result of certain tillage practices apart from decreasing infiltration rate, compaction restricts root growth, decreases nutrient uptake rates and crop yields, and increases erosion, leading to transfer of nutrients and pesticides to surface water (Ball *et. al.*, 1997). With lack of oxygen, the biological activity of the soil is decreased, resulting in slower mineralization of organic matter and reduced availability of plant nutrients. Tillage of the soil produces greater aeration, thus stimulating more microbial activity, and increases the rate of disappearance of soil organic carbon which is a direct measure of organic matter in the soil (Tisdale *et al*., 1993).

In conventional pasture planting systems, disc and mouldboard ploughing techniques lift, turn and mix soil layers with the destruction and burial of above-ground herbaceous vegetation. In this process the residue decomposition is accelerated and there is increased nutrient availability from residues and organic matter oxidation (Calderon *et al.*, 2001).Tillage also results in partial aggregate destruction and concomitant organic matter loss (Wright and Hons, 2005). Organic matter losses from soils worldwide contribute to increased atmospheric CO_2 concentrations (Lal *et al*., 1998). In the highly weathered Ultisols and Oxisols, organic matter is a major determinant of cation exchange capacity, and its reduction leads to a decrease in the nutrient and water retention capability and lower soil fertility. If minimum tillage systems are successful in the establishment and renovation of pastures in these soils, this could improve the sustainability of the soil-plant system due to organic matter preservation.

Most of the carbon (C) losses following soil disturbance such as tillage originate from the active and slow pools, which comprise the biologically defined soil organic pools described as active (labile), slow (partially labile) and passive (stable) (Jenkinson, 1990). The C pools are relative concepts based on the rate of decomposition of particular constituents and more related to biological function than to particular soil chemical C constituents. For example, the active fraction consists of live microorganisms (Microbial biomass), microbial products and unprotected chemical constituents such as proteins and polysaccharides with a turn over time of a few weeks or months. The slow fraction are more resistant to decomposition due to partial physical and chemical protection with a longer turn over time (Theng *et al.*, 1989).The passive organic constituents include humic substances and other macromolecules that are intrinsically resistant against microbial attack due to chemical recalcitrance, physical protection by adsorption on mineral surfaces, or entrapment within soil aggregates (Gregorich *et al.*, 1998). Biological separation of soil organic C (SOC) empirically separates labile from recalcitrant forms by allowing microbes to mineralize C under controlled conditions with the most labile C mineralized first with recalcitrant C mineralized later.

Soil management in both agriculture (Paustian *et al*., 1997) and forestry (Johnson, 1992) often overrides natural factors in determining SOM content. Soil disturbance resulting from deforestation or ploughing up established grassland usually leads to a decrease in SOM content because of enhance decomposition resulting from increased soil aeration and water content. Under arable agriculture, there is also less input of organic matter to the soil than under grass or woodlot. Conversely, reafforestation or establishment of semi-permanent pasture after arable cultivation usually leads to an increase in SOM content. Zero or minimum cultivation often also increases SOM content, especially in the uppermost soil layers.

Tillage practices that disrupt aggregates cause increased breakdown of SOM (Adu and Oades, 1978) and affect the constituent SOM fractions (Cambardella and Elliot, 1994). Conventional tillage systems result in SOC loss (Dalal and Mayer, 1986) and soil aggregate destruction (Tisdale and Oades, 1982) via exposure of physically protected SOM to microbial attack (Beare *et al.,* 1994).

Soil pH

Soil reaction (Soil pH) refers to the degree of acidity or alkalinity of a soil. A soil can be acidic, alkaline or neutral depending on the proportions of hydrogen (H+) or hydroxyl ions (OH-). Acid soils have a higher concentration of hydrogen (H+) than hydroxyl (OH) ions. On the other hand, alkaline soils have a higher concentration of hydroxyl ions than hydrogen ions. A neutral soil has equal concentration of hydrogen and hydroxyl ions. An acid soil has a pH less than 6.5, a neutral soil has a pH of between 6.5 and 7.5 and alkaline soil has a pH of more than 7.5.

The major effects of soil pH are biological. Some organisms in the soil have rather small tolerances to variations in pH, but other organisms can tolerate a wide pH range. Soils with a low pH (pH below 5.0-5.5) can adversely affect crop growth in various ways.

Aluminium, manganese and iron solubility increases as soil pH drops and may become actually toxic to plant at pH below 5.0-5.5. Very acid soils are usually low in available P and have a high capacity to tie up added P by forming insoluble compounds with iron and aluminium. Although very acid soils usually have enough calcium to supply plants needs, they are likely to be low in magnesium and available sulphur and molybdenum. Low pH depresses the activities of many beneficial soil microbes such as those that convert available P, N and S to available mineral form. A soil becomes acid as calcium, magnesium, potassium and sodium ions are leached from profile faster than they are released by mineral weathering and hydrogen and aluminium ions take their places. This can occur as a result of tillage practices which render the soil surface very loose and susceptible to rain drops. This situation exists in high rain forest of the Western Region of Ghana where soils are highly acidic. Soils of drier regions are likely to be alkaline or only slightly acid (Quaye *et al.*, 2003).

Cation Exchange Capacity

Cations surrounding the soil colloidal complex i.e. clay and humic micelle are called exchangeable cations because they can be reversibly replaced equivalently by other cations. For example when ammonium chloride is applied to the soil, then ammonium ions gradually and reversibly replace other cations in equivalent amount. The total number of cation absorption sites per unit weight of soils is called the cation exchange capacity (C.E.C.) of soils. The cation exchange capacity of the soil may be defined as the total number of negative charge per unit weight of the soil. It is expressed in Milliequivalent* per 100gms of soil (Kolay, 1993).

Soil organic matter (SOM) contributes most of the cation exchange capacity (CEC) of A horizons, even of mineral soils with small amounts of SOM. It is especially important in sandy soils and those with clay fractions dominated by minerals with low CEC values, such as kaolinite. Measured CEC values of SOM range from 60 to 300 cmol kg-1 (Leinweber *et al.*, 1993) and, in soils of neutral pH, each weight percentage of SOM contributes up to 3 cmol kg-1 (McBride, 1994). Buol *et al*., (1975) noted that soils with effective cation exchange capacity (ECEC) of 4 me/100g or less had limited ability to retain nutrient cations. SOM also buffers pH. In many soils its buffering capacity is about an order of magnitude greater than that of clay (Curtin *et al.*, 1996).

Soil disturbance resulting from deforestation or ploughing up established grassland usually leads to a decrease in SOM content because of enhance decomposition resulting from increased soil aeration and water content.

Since C.E.C. is enhance by the presence of SOM, any process that will result in the volatilization of organic carbon and for that matter organic matter would also affect the soil C.E. C. Ploughing exposes the soil organic carbon to volatilization. SOM content is determined by the balance between inputs of plants, animals and microbial residues and losses by leaching and evaporation of soluble and volatile products of decomposition. Losses may also occur by soil erosion which is increased by ploughing as a result of exposure of topsoil (Fullen and Catt, 2004).

NPK

The growth of crops depends upon a number of soil and climatic factors, of which the cultivator can control the supply of nutrients and water to crops. He may increase the availability of nutrients in the soil by modifying the soil conditions or may add the nutrients in the form of manures and fertilizers. Crops absorb a large number of elements from the soil. About ninety elements have been found in crops, all of which are not essential to them. Then the question arises which element should be considered as essential to crops. The answer is that an element is considered essential for crops only if it fulfills the three following criteria of essentiality as suggested by D.I. Amon (Kolay, 1993) and takes an active part in the growth and development processes : The crop cannot grow normally and complete its life cycle in the absence of an essential element, the deficiency of an essential element can be corrected by supplying only that particular essential element to the crop and the concerned essential element must play a direct role in plant metabolism (Kolay, 1993). Sixteen elements fulfill the above three mentioned criteria of essentiality of elements and Nitrogen (N), Phosphorus (P) and Potassium (K) are part.

Nitrogen (N)

Nitrogen is a major structural constituent of the cell. It is also an essential constituent of metabolically active compounds like proteins, nucleic acids, chlorophyll and enzymes. Chlorophyll is essential for photosynthesis, nucleic acids are essential for transfer of genetic information and enzymes are biological catalyst (Kolay, 1993). Nitrogen is primarily in ammonium (NH_4 ions) form but is changed by bacteria sooner in the soil to nitrates (NO_3 ions) form. Large amounts of nitrogen are used by plants when they are growing vegetatively and developing their roots, stems and leaves. Nitrogen stimulates the production of these parts at the expense of fruiting and food storage parts (Quaye *et al.*, 2003). When excessive amounts of nitrogen is supplied to crops, they become succulent and when they are adversely affected by unfavourable factors such as deficiency of water, high temperature, insect pests and disease, lodging result. Whenever nitrogen is deficient in the soil, flower buds turn pale and are shed prematurely; fruits are poor in quality, size and weight (Kolay, 1993). Tillage system can influence soil N availability due to its impact on soil organic C and N mineralization and subsequent plant N use or accumulation (Al-Kaisi and Licht, 2004). Compared with NT, the conventional tillage (CT) system can significantly change mineralizable C and N pools (Woods and Schuman, 1988). However, a long-term NT system has potentially greater mineralizable C and N pools compared with CT (Doran, 1980).

Phosphorus (P)

Phosphorus is a component part of proteins, nucleic acids and phospholipids. It promotes root growth, flower, and fruit and seed development and stimulates stiffer stems. Many soils contain large amounts of phosphorus in a form not available to the plant. The availability of phosphorus is related to soil pH; it is most readily available at pH 5-7. Phosphorus is not very soluble in the soil so its movement within the soil profile is low and added remain where it is placed. Thus phosphorus should be worked into the soil to make it available to be absorbed by plant roots (Quaye *et al.*, 2003). Phosphorus is essential for cell division and development of meristematic tissues at the growing points and for root growth. It offsets the harmful effects of excess nitrogen in plants (Kolay, 1993). As nitrogen is affected by the tillage system, phosphorus availability can equally be affected, leading to a phosphorus deficiency in many cropping systems. Many soils have large reserves of total phosphorus, but low levels of available phosphorus (Ortiz-Monasterio *et al*., 2002). Loosening the soil led to a decrease in the available phosphorus content in the 10-25 cm layer without, however, ensuring a higher content in the upper 0-10 cm layer. The same tendency was observed by Ausmane *et al*., (2000) and Maiksteniene (2000) trials.

Potassium (K)

Potassium plays a vital role in the formation of amino acids and proteins from ammonium ions, which are absorbed by roots from the soil. It is also responsible for the transfer of carbohydrates, proteins etc. from the leaves to the roosts. It also plays a vital role in the uptake of other elements particularly nitrogen, phosphorus and calcium. Potassium regulates the permeability of the cellular membrane. It increases the hydration of protoplasm. It activates a number of enzymes, e.g. alcohol dehydrogenase and its deficiency decreases photosynthesis. Potassium increases the resistance of crops to hot and dry conditions and insect pests and diseases. It increases the stiffness of straw in cereals and therefore lodging of cereals is reduced. It improves the quality of fruits and grains (Kolay, 1993). Potassium is soluble in soil and its loss by leaching is controlled by organic matter and the type of clay in the soil (Quaye *et al*., 2003).

2.4 Human Impact on Soil Fertility and Environment

Historically, many past civilizations that collapsed can be attributed to the depletion of the topsoil. Since the beginning of agricultural production in Great plain of North America in 1880s about one half of its topsoil has disappeared. Depletion may occur through a variety of other effects, including over tillage which damages soil structure, over use of inputs such as synthetic fertilizers and herbicides, which leave residues build up that inhabit micro-organisms, and salinisation of soil (Koetke , 1993) .

Human activities have exposed many parts of the natural environment to considerable risk. The first human impact on the environment is on vegetation, which is still prevalent, is the use and misuse of fires. Deliberate burning is use to clear the land for agricultural purposes. Fires cause a reduction in natural vegetation; they threaten wildlife, humans and property. Fire produces secondary problems associated with the clearance of vegetation such as soil erosion, flooding and wind erosion. Deforestation involves the deliberate removal of forest to create new agricultural lands. Deforestation and degradation of other vegetation, particularly near the margins of deserts, have caused once fertile/vegetated lands to become barren in a process called desertification. Factors that contribute to the expansion of desert regions also include bad land management and poor farming techniques (Kevin and Lewis, 1995).

The earth has a limited amount of arable fertile land that can be ploughed to grow crops. This amount is decreasing every year. It is estimated that the arable land in the world will have decreased by one-fifth from 1985-2000 (United Nation Environmental Programme Study, 1990) About 135 million hectares (about 334 acres) will become unusable for farming because the soil will be damaged. The shortage of fertile agricultural land threatens our ability to feed the human population (Karen, 2000)

Mackean (1993) stated that one impact of human on the environment is as a result of intensification of agriculture. Forests and woodlands are cut down and the soil is ploughed up in order to grow more food. This destroys important wildlife habitats and may even affect the carbon dioxide levels in the atmosphere. Tropical rainforest is being cut down at the rate of

43000 square miles per year. Since 1950, between 30 and 50 per cent of British deciduous woodlands have been felled to make way for farm land. The application of pesticides to clear land for farming often kill beneficial creatures that contribute to soil fertility as well as pests.

Land preparation is a combination of tillage practices that places the soil in the best physical condition for plant establishment and crop growth. The aim of land preparation is therefore, in twofold: (i) to place the soil in the best physical condition for crop growth (ii) to ensure that the soil surface is left leveled. To attain this condition, soil must be tilled to a depth so plants can develop a root system which will physically support the plant and also allow the extraction of sufficient moisture and nutrients so yield potential can be realised. Soil disturbance should be sufficient to control weeds. Tillage must leave the soil surface level. Level fields improve water use efficiency and help control in crop weeds. The fields also needs a drainage system that will allow the rapid removal of excess water (www.knowledgebank.irri.org at 11:20 am-28/08/10)

Some of the basic techniques used in farming are clearing of the land, ploughing, fertilization, irrigation and pest control. This practice began with the earliest farmers. People or animal pulled ploughs through the soil. Ploughing the soil (cutting through it and turning it over) helps crops grow by mixing up soil nutrients, loosening soil particles, and uprooting weeds. Organic fertilizers, such as manure, were used to enrich the soil so that plants would grow strong and remain healthy. Fields were irrigated (supplied with water) by digging ditches for water to flow through. Weeds were removed by hand, and some weeds were covered to keep out pests. These ancient methods are still used today. However, on large farms and in industrialized countries, new methods are also used. Machinery is used to plough the soil and harvest crops. Synthetic fertilizers, which are produced in factories, are used instead of manure and plant waste. A variety of over head sprinklers and drip systems are used for irrigation, and many different synthetic chemicals are used to kill pests.

The soil that has taken so long to form is being lost to erosion at an alarming rate. Erosion is the wearing away of the topsoil by wind and water. In the United States, about half of the topsoil has been lost to erosion in the past 200years. Worldwide, it is estimated that about 11 percent of the soil has been eroded in the last 45years. Topsoil erosion is ranked as one of the most serious ecological problem we face. Without the valuable topsoil, crops cannot be grown to feed the world's people.

Certain farming practices can contribute to topsoil erosion. Ploughing produces a loose surface layer of soil that is easily blown away by rain; and harvesting may remove roots and other organic matter that hold soil together. The clearing of forests for farming also contribute to soil erosion. Trees and shrubs absorb large quantities of water. When they are cut down, the amount of water running off the surface of the soil increases, and more soil is carried away. Sometimes the soil washes away slowly, and sometimes large amounts wash away in landslides.

The loss of topsoil occurs all over the world, but it is especially severe in dry areas. Soil in these areas is easily destroyed because it is naturally thin. Soil fertility can deteriorate so much that the land becomes desert like, a process called desertification (Karen, 2000).

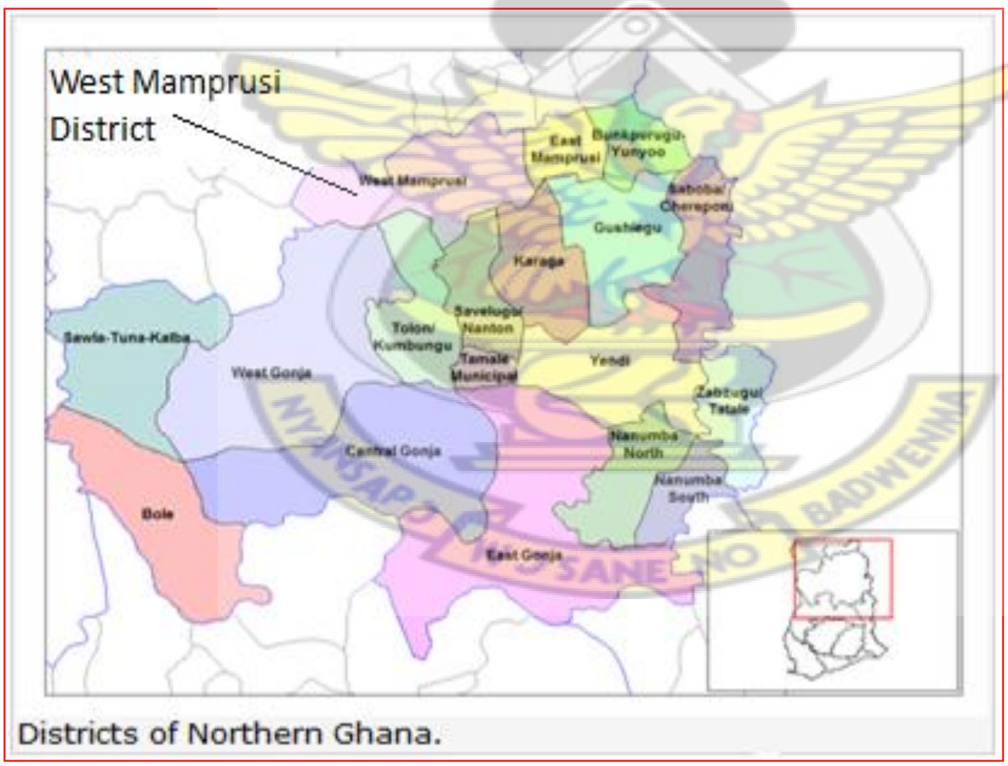
CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

3.1.1Location and Size

The District was created in 1988 under legislative instrument (LI 1448). It is located roughly within longitudes 0°35'W and 1°45'W and Latitude 9°55'N and 10°35'N. The total land area is 5,013 km² and shares boundaries with eleven districts and two regions – Upper East and West. Administratively the district lies within the Northern Region, although it has strong economic and functional linkages with some major settlements in the Upper East Region like Bolgatanga and Fumbisi. See locational maps in terms of national and regional positioning of the District.



Districts of Northern Ghana.

Fig. 1 Districts of Northern Region of Ghana with Study Area Shown by a line

3.1.2 Geology

The District is undulating with gentle slopes from north-east to south-west. There are a few isolated visible outcrops and uplands of not more than 10% slope. Isolated hills, which break the monotony of the landscape, can be found around Karimenga, Shelinvoya, Suhuluya, Manga and the outskirts of Wulugu (WMDA, 2009).

3.1.3 Geological Formation

West Mamprusi District is underlain mainly by the Middle Lower Voltaian, comprising sandstone, arkose, mudstone and shale. The western part of the district is underlain by the lower Voltaian formation consisting of sandstones and grit. The northern tip is underlain by the Birimian rock formations. Birimian rocks are metamorphosed lavas, which ply Units, schists, tufts and greywacke. Regarding the middle Voltaian, the depth and degree of weathering depends on the lithology (WMDA, 2009).

These hold a lot positive effects for the district's development. Most of these stones are rich in potassium, useful for the manufacture of fertilizer for agricultural purposes. They aid in the trapping of moisture laden winds necessary for the formation of rain clouds, and hence rainfall for crop growth. Also, the bases of these hills and mountains are fertile land suitable for the production of food crops. The few hills serve as good attraction for tourism.

3.1.4 Climate and Rainfall Pattern

The district is characterised by a single rainy season, which starts in late April with little rainfall, rising to its peak in July-August and declining sharply and coming to a complete halt in October-November. The area experiences occasional storms, which have implications for base soil erosion depending on its frequency and intensity especially when they occur at the end of the dry season. Mean annual rainfall ranges between 950mm - 1,200mm (WMDA, 2009).The dry season is characterised by Hamattan winds. These winds, which blow across the Sahara desert, are warm and dry causing significantly daily temperatures and causing the soil to lose moisture rapidly. Maximum day temperatures are recorded between March-April of about 45°C while minimum night temperatures of about 12°C have been recorded in December-January. The humidity levels between April and October can be as high as 95% in the night falling to 70% in the day. Night humidity for the rest of the years ranges between 80% and 25% (WMDA, 2009).

3.1.5 Drainage

The district is drained by the White Volta and its tributaries the Sissili and the Kulpawn rivers. Flooding by the White Volta is an annual problem caused mainly by the numerous small rivers, which flow into it especially below Pwalugu. Occasional flash floods have also been caused by spilling of waters from further up stream in Burkina Faso.

The prevailing rainfall and the nature of the underlying rock formations determines to a large extent the ground and surface water potential for the district. The present combination of heavy run-off, high evaporation and transpiration and low infiltration rates to recharge aquifers in some areas in the district, contribute to water deficiencies especially to the west of the White Volta, the south around Fio area and eastern parts around Shelinvoya.

3.1.6 Vegetation

The natural vegetation of the district is classified as Guinea Savannah Woodland, composed of short trees of varying sizes and density, growing over a dispersed cover of perennial grasses and shrubs. The climatic conditions, relief features and soil texture which foster water logged conditions (especially in the area west of the White Volta) in the rainy season and draughty soils in the dry season tend to develop a characteristically hardy tree vegetation adapted to long periods of dry spells.

The existence of dense woodlands and forests along river valley (especially areas along the basin of the White Volta and its tributaries) is gradually beginning to change due to the influx of people into these areas as a result of the successful control of river borne diseases (e.g. Onchocerciasis). The vegetation is also annually affected by bush fires, which sweep across the savannah woodland each year.

3.1.7 Soils

The soils of this area are Savanna Ochrosols. These are similar to the Forest Ochrosols except that they occur in the savanna areas with semi-arid climatic conditions. Though the soils are moderately deep to deep, the solum is relatively thinner than their forest counterparts. Decomposing rock or hard rock may be encountered within 150 cm depth. The topsoils are generally thin (<20cm), grayish brown sandy loam, weak granular and friable. The subsoil range from red in summits to brownish yellow middle slope soils (especially on some sandstone soils). Ironstone concretions and sandstone brashes of about 10-40 per cent commonly occur in some of these soils. Further differentiation into Red and Yellow Savanna Ochrosols is made at the great soil subgroup level. Several soil series have also been identified in this group of soil. The bulk of the country's food crops are grown on these soils. The soils support crops such as yams, maize, cowpea, soybean, millet, groundnuts, sorghum and cassava. Farmers in West Mamprusi District are involved in the cultivation of these crops using various land tillage practices. The main limitations of this soil type are moisture availability, which is climatic and nutrient availability which is compounded by agricultural land preparation practices. The soils are rather impoverished through continuous cropping/short fallows without nutrient amendments. Erosion hazard is also a serious problem on steep slopes though most parts of the savanna are generally low lying (Brammer, 1962).

3.3 Methodology

The components of the research were in two fold. The first primarily involved the use of a survey to collect data from farmers on their perception on the environment as well as their farming practices on the fertility of the soil. The second part involved the collection of soil samples from the field and analyzing them in the laboratory to determine their nutrients status.

3.3.1 Survey

A survey was conducted to execute the first part of this research proposal. Questionnaires were used as a survey data collection technique to primarily identify the type of land tillage practices in selected areas. The questionnaire items involved both the use of closed-ended as well as open-ended types that were carefully designed to secondarily collect information from the population on their knowledge on their land tillage practices on soil fertility and the environment in general. A total of one hundred and twenty (120) questionnaires were administered in ten (10) communities, with twelve (12) questionnaires in each community. Selections of communities were based on population size, accessibility and prevalence of tillage practices. Farmers were the sampling universe. Non-randomized sampling procedure was used with judgmental or purposive sampling technique.

3.3.2 Field Work

The sampling sites of the soil were selected based on:

- Responses from the survey which indicated the prevalence of tillage practices of interest

- The uniqueness of sampling sites which was the tillage practices namely; use of tractors (Tp), bullocks (Bp), hand hoeing (Hh) and zero tillage (Zt).
- Farmers who tilled their lands by these methods were selected in these communities and soil samples collected from their farms
- These farmers practiced Good Agronomic Practices (GAPs) such as seed selection, planting practices, spacing, use of required plant population/density procedures, timely weed control measures etc. but differed only in the method of tillage.

100g of disturbed soil each in duplicate was collected in each site using a bulk density ring with a volume of 78.5cm^3 by the help of a mallet, a hand trowel, a rule and a knife into polythene bags and sent to the laboratory for nutrient evaluation. Soil samples were collected in three (3) locations in the district namely: Wulugu (Blk 1), Kparigu (Blk 2) and Wungu (Blk 3) (Fig. 2).

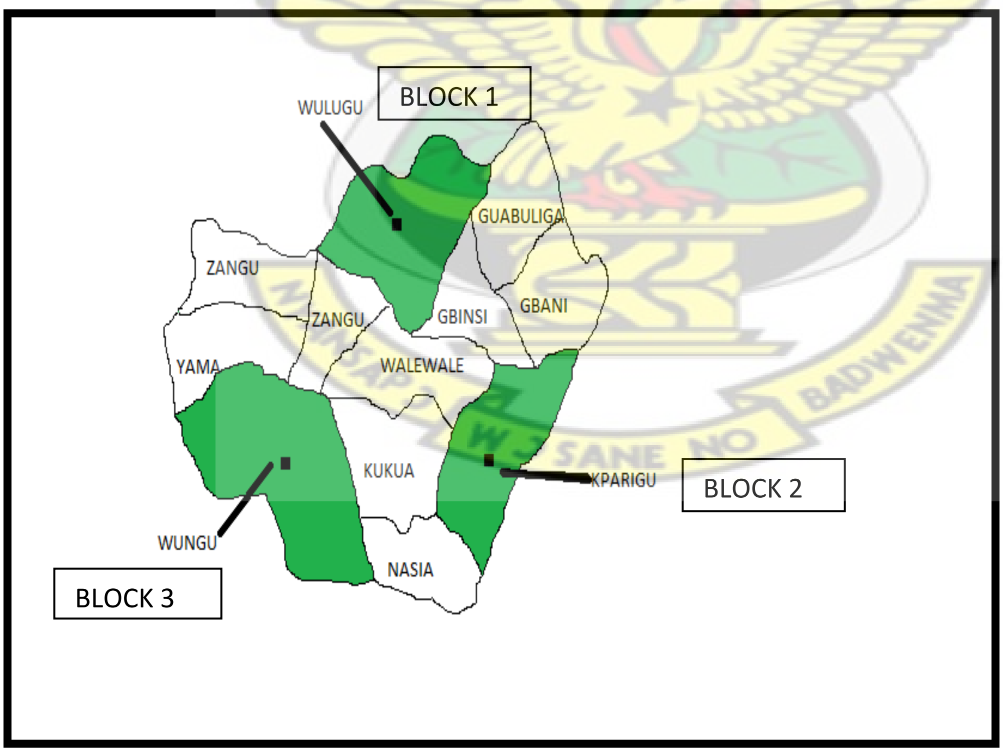


Fig. 2 Soil Samples Collection Sites in the West Mamprusi District

Sixty (60) different soil samples were taken from: Topsoil from Tractor plough (TpT) and Subsoil from Tractor plough (TpS), Topsoil from Bullock plough (BpT) and Subsoil from Bullock plough (BpS), Topsoil from Hoe/Traditional tillage (HpT) and Subsoil from Hoe/Traditional plough (HpS), Topsoil from Zero tillage or use of chemicals (ZpT) and Subsoil from Zero tillage/use of chemicals (ZpS) and Topsoil from Fallow land (FlT) and Subsoil from Fallow (FlS). The depth of Topsoil was 0-15cm and that for Subsoil was 15-30cm. Randomized Complete Block Design (RCBD) was used where the communities served as the blocks whiles the tillage practices were the treatments as shown below.

TABLE-1 Illustration of Randomized Complete Block Design (RCBD) Used for Study

	BLOCK 1 (WUNGU)	**BLOCK 2 (KPARIGU)**	**BLOCK 3 (WULUGU)**
TREATMENTS			
	BpT	BpT	BpT
	BpS	BpS	BpS
	TpT	TpT	TpT
	TpS	TpS	TpS
	HpT	HpT	HpT
	HpS	HpS	HpS
	ZpT	ZpT	ZpT
	ZpS	ZpS	ZpS
	FlT	FlT	FlT
	FlS	FlS	FlS

Remarks: BpT=Bullock plough topsoil BpS=Bullock plough subsoil TpT=Tractor plough topsoil TpS=Tractor plough subsoil HpT=Hand hoed topsoil HpS=Hand hoed subsoil ZpT=Zero tillage topsoil ZpS=Zero tillage subsoil FlT=Fallow land topsoil FlS=Fallow land subsoil

3.3 Parameters Determined

Physical and chemical properties of the soils were determined from the soil samples since the fertility of any given soil is influenced by these factors.

3.3.1 Physical Properties

3.3.1.1 Bulk density

The bulk density of the soil samples were determined by the core method. Soil samples were collected using bulk density rings of known volume of 78.5cm^3. The soils were then dried in an oven to 105°C for 24 hours and allowed to cool to a state where the difference between weight of soils were less than 0.01g. The ratio of weight of each air dried soil sample to that of volume of the core sampler or volume of the ring was calculated to give the bulk density (Blake and Hartge, 1982).

The formular used was:

$$Db = \frac{w1 - w2}{v}$$

Where:

Db = bulk density

W1 = weight of wet soil sample

W2 = weight of soil dried at 105 °C

V = volume of cylinder

3.3.1.2 Particle Size Distribution

The particle size distribution was determined using the Hydrometer method (Day, 1965). Fifty grammes of air dried soil was put into a 200ml container. 100ml of hexametaphosphate (HMP) solution was added capped and placed on reciprocating horizontal shaker for 16 hrs. The suspension was quantitatively transferred into a sedimentation cylinder and deionized water was added to bring to 1.0L final volume. The suspension was allowed to equilibrate to room temperature for 2 hrs. A plunger was then inserted to thoroughly mix the contents, dislodging sediment from the bottom of the cylinder. A hydrometer was then lowered carefully into the suspension after 30 seconds to take the density of the suspension after 40 seconds and this was recorded to represent silt content. The content in the cylinder was then poured on a sieve and material on sieve dried and this represented sand. The filtrate was then allowed to stand for 4 hrs and the density of the suspension was taken again to represent clay content. The textural triangle was then used to find the textural classes for the various soil samples (Anderson and Ingram, 1993).

3.3.2 Chemical Properties

3.3.2.1 pH

Soil pH was determined in a 1:1 suspension of soil and water using a HI 9017 Micro-processor pH meter. A 25 g of soil sample was weighed into 100 ml polythene bottle. To this, 50ml distilled water was added from a measuring cylinder and the bottle capped. The solution was shaken on a reciprocating shaker for two hours. After calibrating the pH meter with buffer solution at pH 4.0 and 7.0, pH was read by immersing the electrode into the upper part of the suspension.

3.3.2.2 Organic Carbon

Organic carbon content was determined by a modified Walkley-Black procedure as described by Nelson and Sommers (1982). This procedure involvesd a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After reaction, the excess dichromate was titrated against ferrous sulphate. 1.0 g of soil sample was weighed into an Erlenmeyer flask. A reference sample and a blank were included. 10 ml of 1.0 N (equivalent to 0.1667M) potassium dichromate solution was added to the soil and the blank flask. To this, 20 ml of concentrated sulphuric acid was carefully added from a measuring cylinder, swirled and allowed to stand for 30 minutes in a fume cupboard. Distilled water (250ml) and concentrated orthophosphoric acid (10.0 ml) were added and allowed to cool. One millilitre of diphenylamine indicator was added and titrated with 1.0 M ferrous sulphate solution.

Calculation of organic carbon:

Per cent organic carbon content of soil was calculated as follows:

$$\%\ \text{Organic C} = \frac{\text{M} \times 0.39 \times (\text{V1} - \text{V2})}{\text{s}}$$

Where:

M = molarity of ferrous sulphate solution

V1 = ml ferrous sulphate solution required for blank

V2 = ml ferrous sulphate solution required for sample

S = weight of air-dry sample in grams

0.39 = 3×0.001×100% 1.3 (3-equivalent weight of C)

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

3.3.2.3 Extraction of the Exchangeable Bases

A 10 g sample of soil from each treatment was transferred into a leaching tube and leached with 250 ml of buffered 1.0 M ammonium acetate (NH_4OAc) solution at pH 7.

3.3.2.4 Determination of Calcium and Magnesium

For the determination of the calcium and magnesium, a 25 ml portion of the extract was transferred into an Erlenmeyer flask and the volume made to 50 ml with distilled water. A 1.0 ml portion of hydroxylamine hydrochloric, 1.0 ml of 2.0 % potassium cyanide (from burette), 1.0ml of 2.0 % potassium ferrocyanide, 10.0 ml ethanolamine buffer and 0.2 ml Eriochrome Black T solution were added. The solution was titrated with 0.01 M EDTA (ethylene diamine tetraacetic acid) to a pure turquoise blue colour. 20 ml 0.01 M magnesium chloride solution was also titrated with 0.01 M EDTA together with 25 ml of 1.0 ml M ammonium acetate solution to provide a standard blue colour for titration.

3.3.2.5 Determination of Calcium

A 25 ml portion of the extract was transferred into a 250 ml Erlenmeyer flask and the volume made to 50 ml with distilled water. To this, hydroxylamine hydrochloride (1.0 ml), potassium cyanide (1.0 ml of 2 % solution) and potassium ferrocyanide (1.0 ml of 2 %) were added. After a few minutes, 4 ml of 8 M potassium hydroxide and a pinch (0.1g) of murexide indicator were added. The solution obtained was titrated with 0.01 M EDTA solution to a pure blue colour.

Twenty millilitres of 0.01 M calcium chloride solution was titrated with 0.01 M EDTA together with 25 ml 1.0 M ammonium acetate solution to provide a standard pure blue colour.

Concentration of Ca + Mg was calculated from the formular:

$$\text{Ca + Mg (or Ca) (cmol/kg soil)} = \frac{0.01 \times (\text{Va} - \text{V}b) \times 1000}{0.1 \times \text{W}}$$

Where:

W = weight in grammes of oven dry soil extract

Va = ml of 0.01 M EDTA used in the titration

Vb = ml of 0.01 M EDTA used in blank titration

0.01 = concentration of EDTA used

$$\text{Ca} = \text{Mg(or Ca)}(\frac{\text{cmol}}{\text{kg}}\text{soil}) = \frac{0.01 \times (\text{Va} - \text{Vb}) \times 1000}{0.1 \times \text{W}}$$

3.3.2.6 Exchangeable Potassium and Sodium Determination

Potassium and sodium in the percolate were determined by flame photometry. A standard series of potassium and sodium were prepared by diluting both 1000 mg/l potassium and sodium solutions to 100 mg/l. This was done by taking a 25 ml portion of each into one 250 ml volumetric flask and made to volume with water. Portions of 0, 5, 10, 15, and 20 ml of the 100 mg/l standard solution were put into 200 ml volumetric flasks respectively. One hundred millilitres of 1.0 M NH_4OAc solution was added to each flask and made to 200ml volume by distilled water. The standard series obtained was 0, 2.5, 5.0, 7.5, 10.0 mg/l for potassium and sodium. Potassium and sodium were measured directly in the percolate by flame photometry at wavelengths of 776.5 and 589.0 nm respectively.

Calculations:

$$\text{Exchangeable K (cmol/kg soil)} = \frac{(a-b)\times 250}{10\times 39.1\times s}$$

$$\text{Exchangeable Na (cmol/kg soil)} = \frac{(a-b)\times 250}{10\times 23\times s}$$

Where:

a = mg/l K or Na in the diluted sample percolate

b = mg/l K or Na in the diluted blank percolate

s = air dried sample weight of soil in grams

(Warncke and Brown, 1998)

3.3.2.7 Exchangeable Acidity

Exchangeable acidity is defined as the sum of Al and H (Mc Lean, 1965). The soil sample was extracted with unbuffered 1.0 M KCl, and the sum of Al and H was determined by titration. 50 grammes of soil sample was put in a 200 ml plastic bottle and 100 ml of 0.1 M KCl solution added. The bottle was capped and shaken for 2.0 hrs and then filtered. 50 millilitres portion of the filtrate was taken with a pipette into a 250 ml Erlenmeyer flask and 2 drops of phenolphthalein indicator solution added. The solution was titrated with 0.1 ml NaOH until the colour just turned permanently pink.

Calculation:

$$\text{Exchangeable acidity (cmol/kg soil)} = \frac{(a-b) \times M \times 2\ 100}{s}$$

Where:

a = ml NaOH used to titrate with sample

b = ml of NaOH used to titrate with blank

M = molarity of NaOH solution

S = air dried soil sample weight in grams

2= 100/50 (Filtrate/pipette volume)

(Mc Lean, 1965).

3.3.2. 8 Effective Cation Exchange Capacity

Effective cation exchange capacity was determined as the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) and exchangeable acidity (Al^{3+} and H^{+}).

3.3.2.9 Base Saturation

Base saturation refers to the magnitude of the exchangeable bases that occupy the exchange complex. Base saturation was determined by the ratio of the total exchangeable bases to that of effective cation exchange capacity expressed as a percentage.

3.3.2.10 Total Nitrogen

Total nitrogen was determined by the Kjeldahl digestion and distillation procedure as described in Soil Laboratory Staff (1984). 0.2 g of soil sample was put in a flask and the volume made to 100 ml with water and mixed well. A 25 ml aliquot of the solution was transferred to the reaction chamber and 10.0 ml of 40 % NaOH solution was added followed by distillation. The distillate was collected in 2 % boric acid. The distillate was titrated with 0.02 N HCl solution with bromocresol green as indicator. A blank distillation and titration was also carried out to take care of traces of nitrogen in the reagents as well as the water used.

Calculation:

The % N in the sample was expressed as:

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

Where:

N = concentration of HCl used in titration

a = ml HCl used in sample titration

b = ml HCl used in blank titration

s = weight of air-dry sample in gram

3.3.2.11 Available Phosphorus

The readily acid-solution forms of P were extracted with a HCl: NH_4F mixture called the Bray's No. 1 method as described by Bray and Kurtz (1945) and Olsen and Sommers (1982).

Phosphorus in the extract was determined on a spectrophotometer by the blue ammonium molydate with ascorbic acid as reducing agent.

A 5.0 g soil sample was weighed into a shaking bottle (35 ml) and 20 ml of extracting solution of Bray-1 (0.03 M NH_4F and 0.025 M HCl) was added. The sample was shaken for one minute by hand and then immediately filtered through a fine filter (Whatman No. 42). One mililitres of the standard series, the blank and the extract, 2 ml boric acid and 3 ml of the colouring reagent (ammonium molybdate and antimony tartarate solution) were pipetted into a test tube and homogenized. The solution was allowed to stand for 15 minutes for the blue colour to develop to its maximum. The absorbance was measured on a spectronic 21D spectrophotometer at 660nm wavelength.

A 0.2 g of oven dry monobasic potassium phosphate KH_2PO_4 was dissolved and diluted to one litre with distilled water. 0.5, 1.0, 2.0, 4.0 and 6.0 ml of 50 ppm P standard solution was pipetted into 50 ml volumetric flask and made to mark with distilled water. These contained 0.5, 1.0, 2.0, 4.0, and 6.0 ppm phosphorus.

Calculations:

$$\text{P (mg/kg} = \frac{(\text{a} - b) \times 20 \ \times 6}{s}$$

Where:

a = mg/l P in sample extract

b = mg/l P in blank

s = sample weight in grams

20 = ml extracting solution

6 = ml final sample solution

3.4 Data and Analysis

Data obtained were analysed using SPSS whilst results were further subjected to Analysis of Variance (ANOVA) using the GENSTAT Statistical package and treatment means were compared using Duncan's Multiple Range Test (DMRT) at P = 0.05 probability level (Steel *et al.,* 1997) .

CHAPTER FOUR

RESULTS

4.1 Survey

4.1.1 Background Information of Respondents

The educational level of the respondents in the survey was sought where the survey indicated that 27 respondents of the 120 sampled were educated at least to primary level representing 23 % of the 120 sampled whiles 93 of the 120 sampled were not educated representing 77 % (Fig 3).

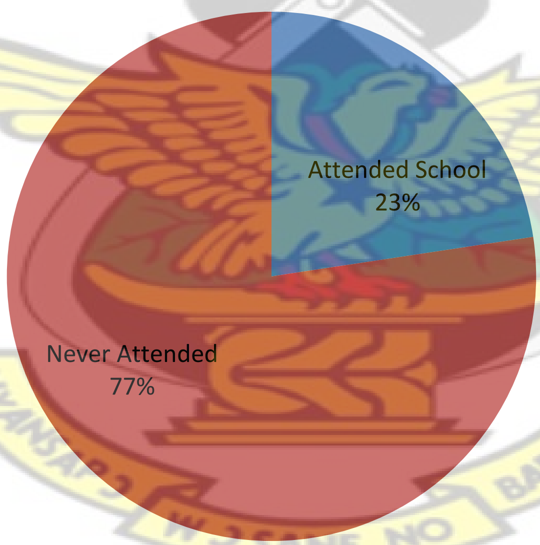


Fig. 3 Educational level of Respondents in the Survey

The occupations of the respondents among others included farming where 115 of the 120 sampled were engaged in it representing 96 %. One each of the respondents of the 120 sampled was engaged in non-governmental organization and other forms of occupations representing 1 % each respectively whilst 3 respondents of the 120 sampled were engaged in government employment representing 2 % (Fig. 4).

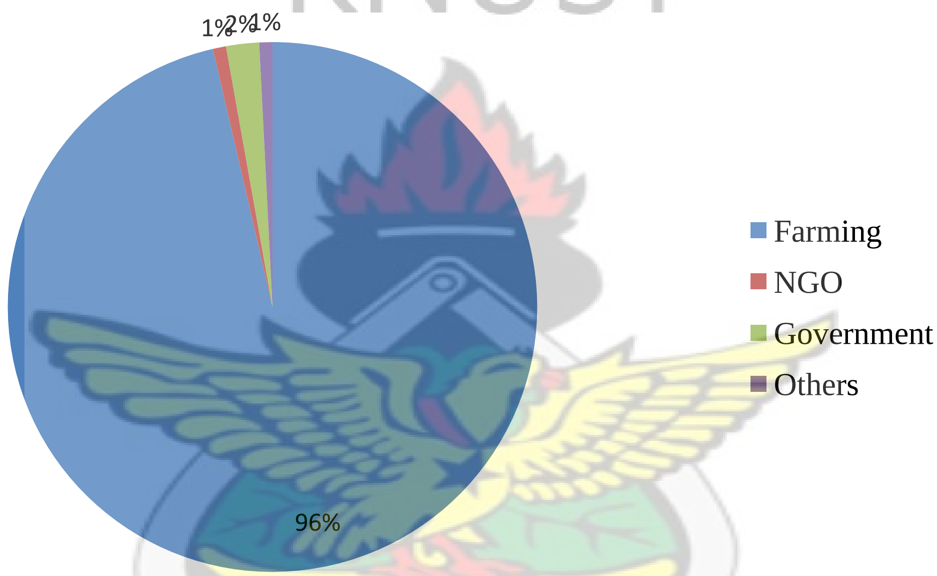


Fig. 4 Occupation of Respondents

4.1.2 Types of Tillage Practices in District

Tillage practices in the district were tractor plough (Tp), bullock plough (Bp), traditional hand hoeing (Hh) and zero tillage (Zt) or the use of agro-chemicals. Tractor ploughs had the largest percentage of 44.2% representing 53 respondents of the 120 sampled, followed by zero tillage with 27.5% representing 33 respondents of the 120 sampled. Bullock ploughs and traditional hand hoeing were 15.8 and 12.5% representing 19 and 15 respondents of the 120 sampled respectively (Fig. 5).

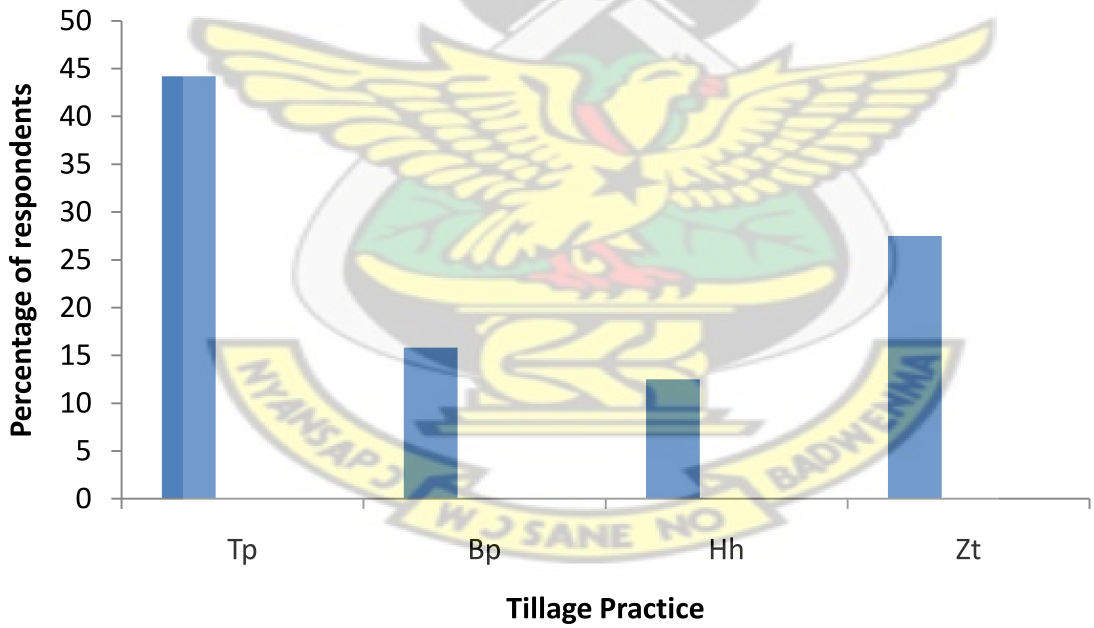


Fig. 5 Types of Tillage Practices

4.1. 3 Knowledge of Farmers on Effect of Tillage on Soil Fertility

The survey revealed that 96 respondents did not know of the effects of their land tillage practices on soil fertility. This represented 80 % of the 120 sampled. However, 24 respondents representing 20 % had some knowledge in one form or the other on the effects of their tillage practices on soil fertility (Fig. 6).

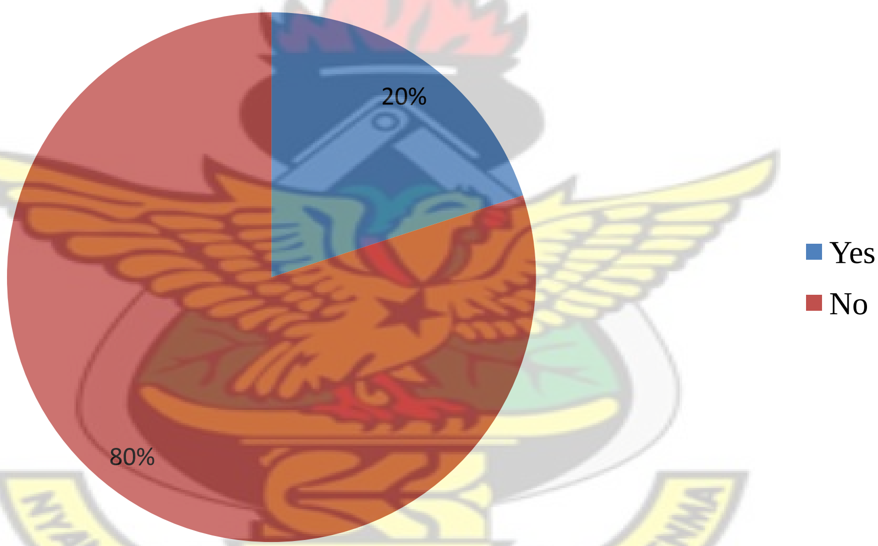


Fig. 6 Knowledge of Effect of Tillage on Soil Fertility

4.1.4 Farmers Opinions on Tillage Effects on Soil Fertility

The opinions of farmers were sought during the survey as to the effects of tillage practices on soil fertility. 27 % of sampled population held the view that tractor plough and planting had effects on soil fertility whiles 71 % of them indicated that the use of agro-chemicals had more effects. Traditional hand hoeing recorded the least value of 2 % (Fig. 7).

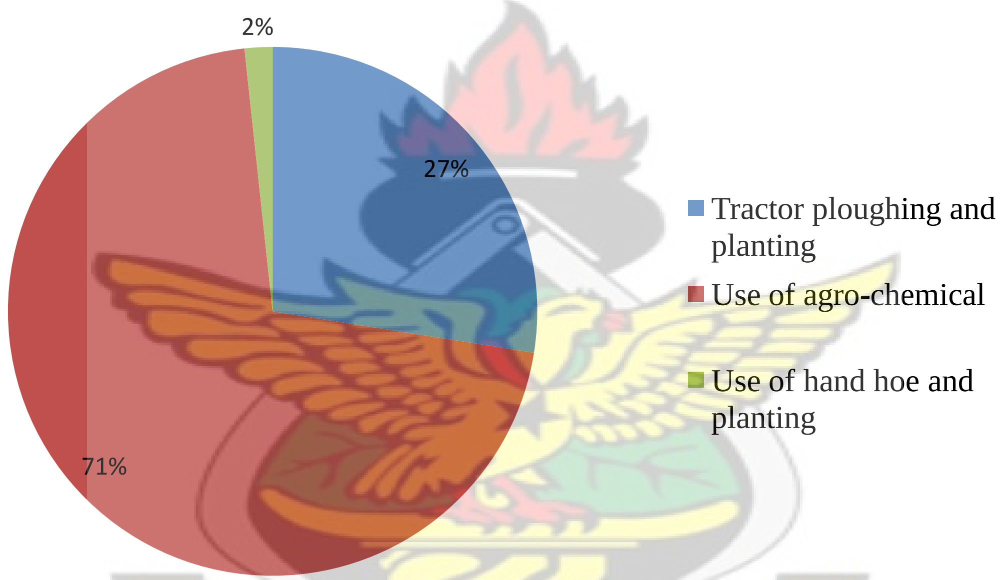


Fig. 7 Opinions of Farmers on Effects of Tillage on Soil Fertility

4.1.5 Farmers Information About Organic Farming /Sustainable Agriculture and their Opinions on How to Protect the Environment to Maintain Soil Fertility

Ninety two respondents of the 120 sampled had information about sustainable agriculture/organic farming representing 77 % whilst 28 respondents of the 120 sampled had not heard about this representing 23 % (Fig. 8). Among the sustainable/organic farming practices, respondents had heard included use of poultry and farm yard manure, compost, crop rotation as well as crop residues use.

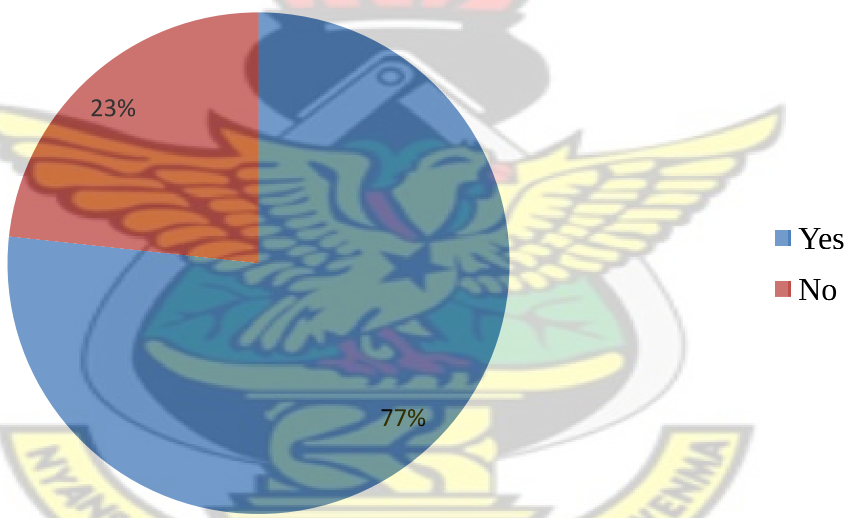


Fig. 8 Farmers Heard About Organic Farming

On organic farming or sustainable agriculture practices undertaken by respondents for the past 3years, respondents indicated use of poultry and farm yard manure, use of compost, practice of crop rotation and crop residues use as the organic farming practices undertaken. These represented 37 %, 21 % and 42 % (Fig.9).

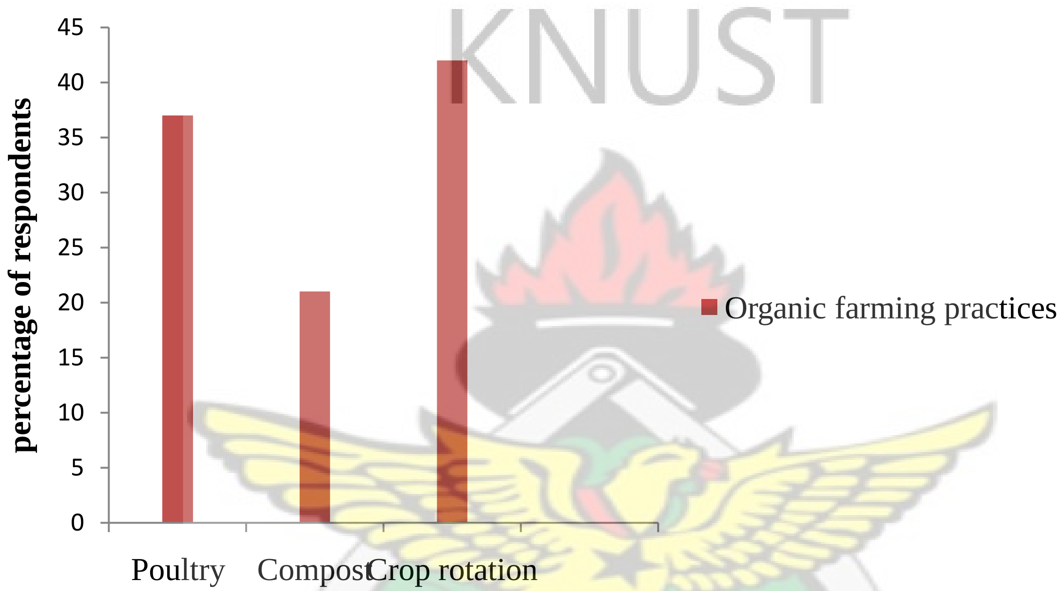


Fig. 9 Organic Farming Practices by Farmers

The opinions of respondents on how to maintain soil fertility was also sought. Respondents indicated (1) avoidance of farming near water bodies and the practice of crop rotation, (2) avoidance of extensive use of chemicals and use of crop residues as well as (3) avoiding deforestation and practicing fallow system were noted by respondents as the surest ways to maintain soil fertility and to protect the environment from degradation. The corresponding percentages for these practices revealed by the survey were: 23 %, 33 % and 44 % respectively (Fig. 10).

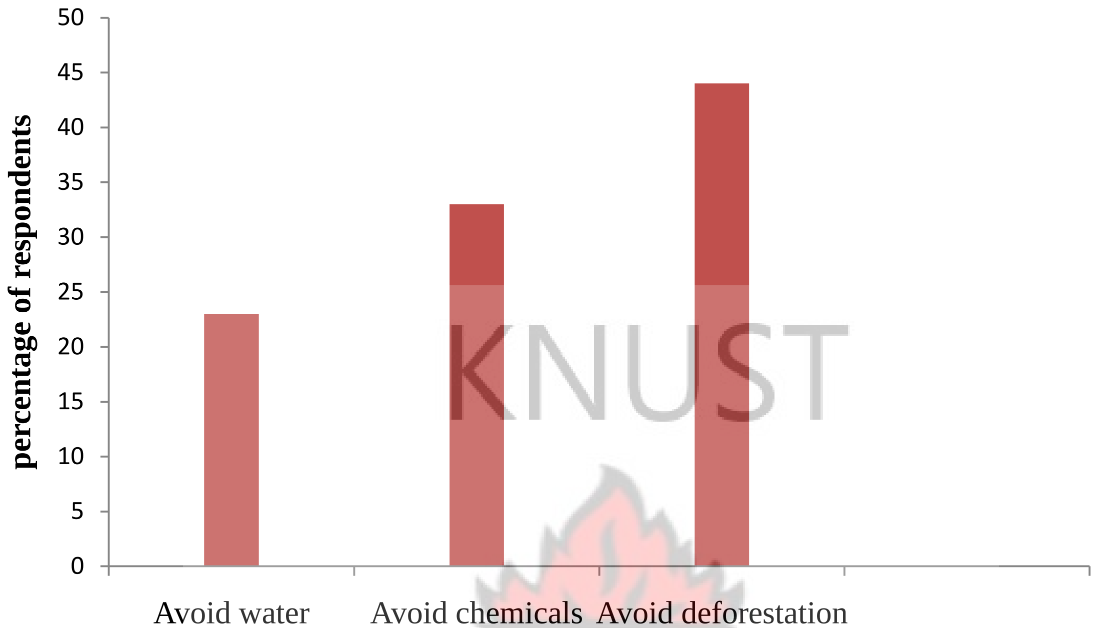


Fig. 10 Farmers Opinions on Maintenance of Soil Fertility

4.1.6 Tillage Practices and Yield of Maize in Bags/Acre

Figure 11 indicates the mean yield of maize from the various tillage practices. There was a significant difference $P< 0.05$, DMRT between Hand hoed (Hh) and Zero tillage (Zt) with a larger number of bags recorded by Zero tillage. Zero tillage had the highest yield of 6.5 bags/acre ie (650 kg) whilst hand hoed obtained the least of 5.0 bags/acre ie (500 kg). The average yield from these tillage practices however, was 570 kg representing 5.7 bags/acre. The difference between the highest yield and that of the lowest was 150 kg representing 1.5 bags. The differences in yields among the tillage practices was 50 kg or 0.5 of a bag except between the highest and the lowest which was 1.5 bags.

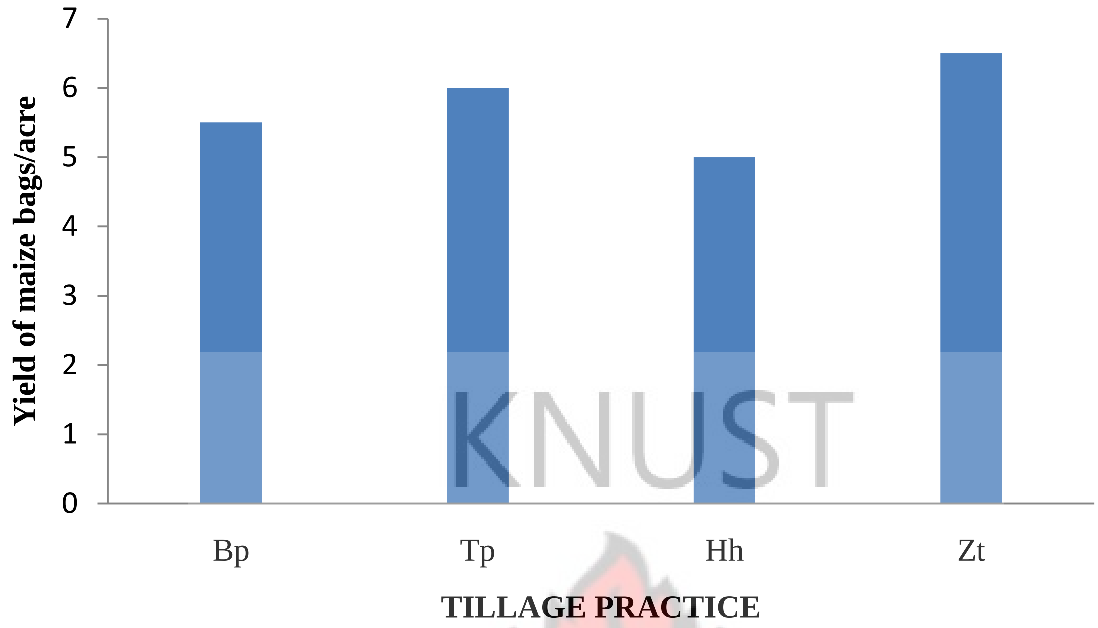


Fig. 11 Tillage Practices and Yield of Maize in Bags/Acre (Bp= Bullock plough Tp= Tractor plough Hp= Hands hoeing Zt= Zero tillage)

4.2.1 Tillage Practices and Bulk Density

There were no significant differences P > 0.05, DMRT among the treatments with regards to bulk density of the soil. The subsoil for the no tillage recorded the highest bulk density of 1.4 g/cm ^{3} whilst the lowest bulk density of 1.2 g/cm ^{3} was recorded by bullock plough subsoil and tractor plough top and subsoil. The bulk density of the topsoil for the bullock plough was higher than the subsoil. Except the zero tillage whose subsoil was higher than its topsoil and also recorded the highest bulk density, the rest of the tillage practices recorded equal bulk density for top and subsoils (Fig. 12).

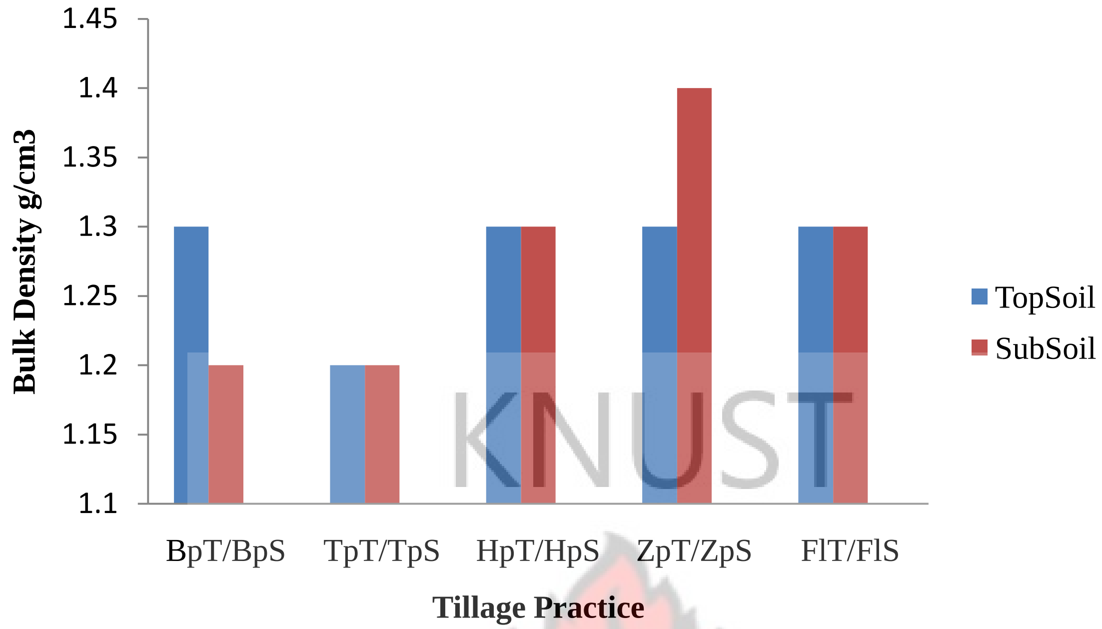


Fig. 12 Tillage Practices and Mean Bulk Density (BpT= Bullock plough topsoil BpS= Bullock plough subsoil TpT= Tractor plough topsoil TpS= Tractor plough subsoil HpT= Hand plough topsoil HpS= Hand plough subsoil ZpT= Zero tillage topsoil ZpS= Zero tillage subsoil FlT= Fallow land topsoil FlS= Fallow land subsoil)

4.2.2 Tillage Practices and Particle Size Distribution

The proportions of the soil particles of the sampled areas were sand ranging from 83.4-29.2 % indicated in HpT and ZtS respectively. Silt content was 62.8-4.0 % for ZtS and TpT respectively whiles majority of the tillage practices had clay content of 12.0 % with HpT recording the least percentage of 4.0 The textural classification of the study area generally indicated 20 % sandy loam, 30 % loamy sand, 30 % silt loam and 20 % loam soil. Result indicated generally high sand content of 83.4 % and very low clay content of 4.0 %. There were however, no marked differences in the texture with regards to topsoil and subsoil of the various tillage practices (Table-2).

Table-2 Tillage Practices and Particle Size Distribution

TILLAGE PRACTICES	SAND %	SILT%	CLAY%	TEXTURE
BpT	40.0	48.0	12.0	Loam
BpS	76.0	11.0	12.0	Sandy Loam
TpT	83.4	4.6	12.0	Sandy Loam
TpS	82.2	9.8	8.0	Loamy Sand
HpT	83.4	12.6	4.0	Loamy Sand
HpS	83.3	8.7	8.0	Loamy Sand
ZtT	37.9	50.1	12.0	Silt Loam
ZtS	29.2	62.8	8.0	Silt Loam
FlT	53.4	38.6	8.0	Loam
FlS	29.3	58.7	12.00	Loam

Remarks: BpT= Bullock plough topsoil BpS= Bullocks plough subsoil TpT= Tractor pough topsoil TpS= Tractor plough subsoil HpT= Hand hoe topsoil HpS= Hand hoe subsoil ZtT= Zero tillage topsoil ZtS= Zero tillage subsoil FlT= Fallow land topsoil FlS= Fallow land subsoil

4.2.3 Tillage Practices and Organic Carbon

Figure 13 shows percentage organic carbon content for the tillage practices. Results did not show significant differences among the tillage practices $P > 0.05$, DMRT. The highest organic carbon content of 0.7 % was recorded by fallow land topsoil whilst tractor plough subsoil recorded the least of 0.1 %. However, except the hand hoe tillage practice whose subsoil recorded higher organic carbon content than its topsoil, the topsoil of the rest of the tillage practices recorded more organic carbon content than their subsoils. Similar trend was observed among and between their sub soils. The mean organic carbon content was 0.4 %.

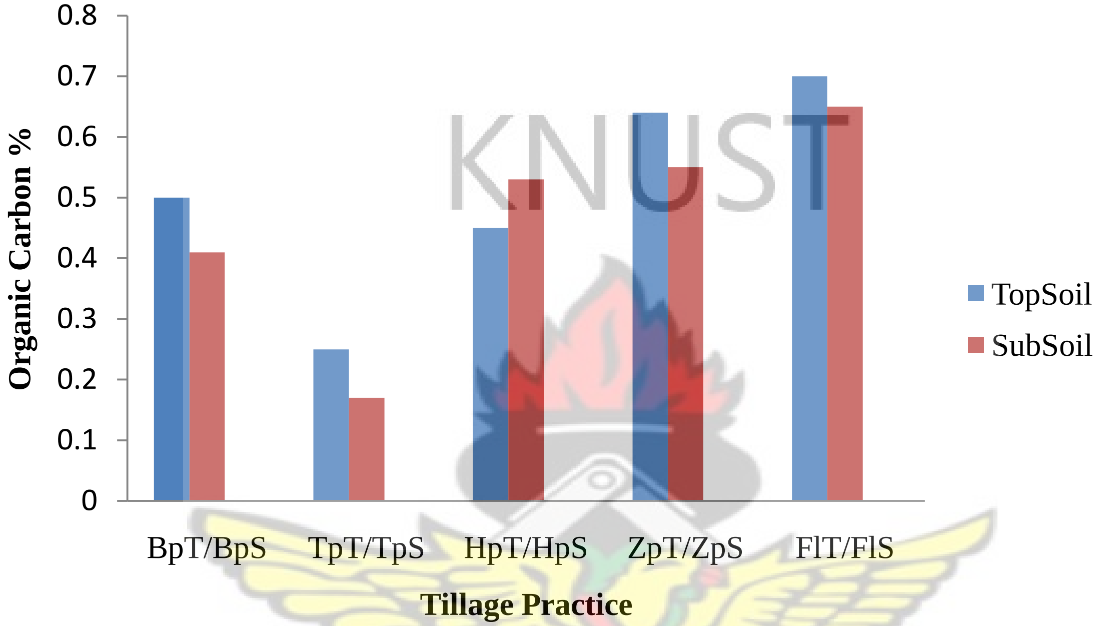


Fig. 13 Tillage Practices and Organic Carbon

4.2.4 Tillage Practices and Organic Matter

Figure 14 shows organic matter content for the tillage practices. There were no significant differences among the tillage practices P > 0.05 DMRT. Fallow land topsoil contained the largest organic matter content of 1.2 % whilst tractor plough subsoil recorded the least of 0.2 %. Similar scenario was observed between and among their sub soils where fallow land subsoil recorded the largest value of 1.1 % whilst tractor plough subsoil maintained the least value of 0.2 %.

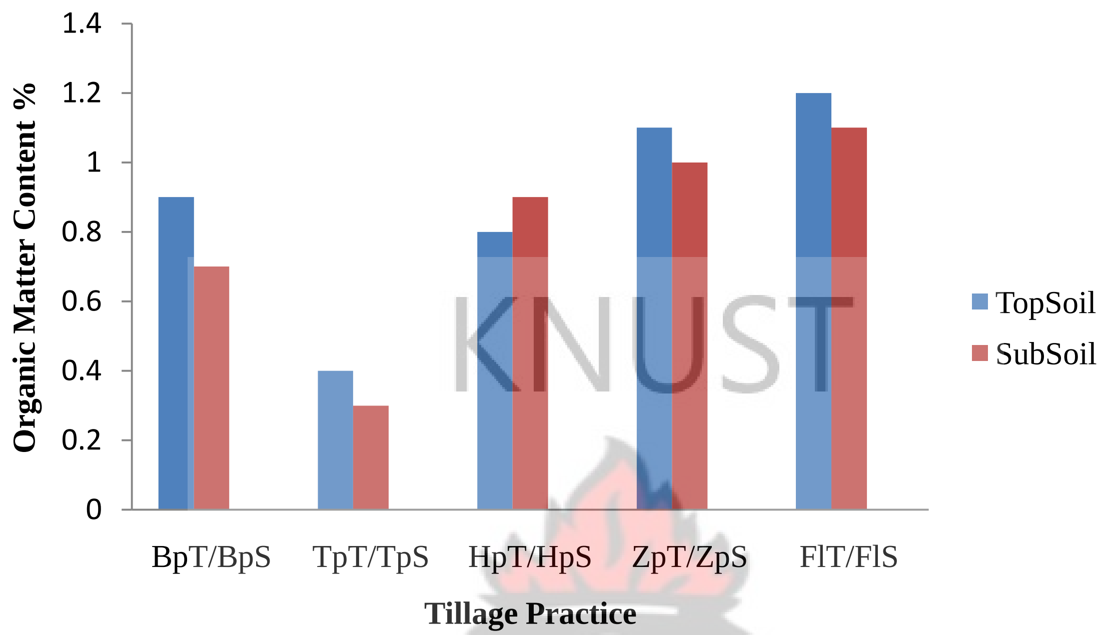


Fig. 14 Tillage Practices and Organic Matter

4.2.5 Tillage Practices and Total Exchangeable Bases

There were significant differences P< 0.05 DMRT with regards to fallow land and rest of the tillage practices. Fallow land topsoil recorded the highest total exchangeable bases as well as effective cation exchange capacity of 10.9 me/100g with the least value of 3.9 me/100g recorded by tractor plough topsoil. Apart from tractor plough topsoil whose subsoil had its T.E.B being higher than its topsoil, the rest of the tillage practices recorded higher values for their topsoil than the subsoil.

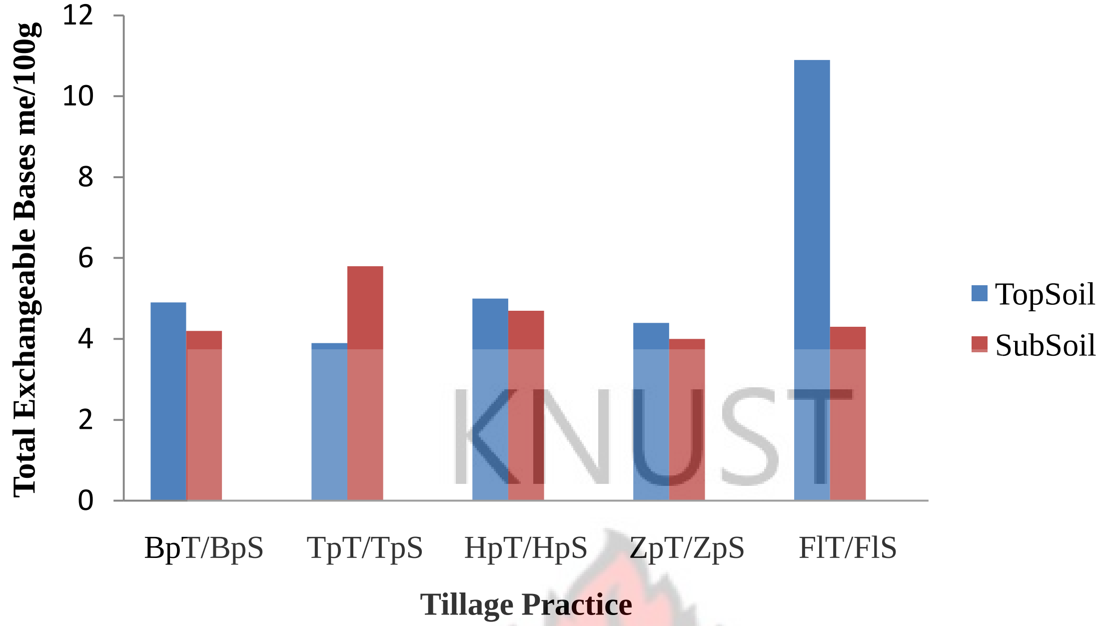


Fig. 15 Tillage Practices and Total Exchangeable Bases

4.2.6 Tillage Practices and Effective Cation Exchange Capacity

Figure 16 shows effective cation exchange capacity for the tillage practices. There were significant differences P< 0.05, DMRT between fallow land and rest of the tillage practices. The largest value of 11.5 me/100g of soil and a least value of 4.1 me /100g of were recorded by fallow land topsoil and tractor plough topsoil respectively. With the exception of tractor plough topsoil whose subsoil had its E.C.E.C. being larger than its topsoil, the rest of the tillage practices recorded larger values for their topsoil than the subsoil. Similar trend was observed in their sub soils.

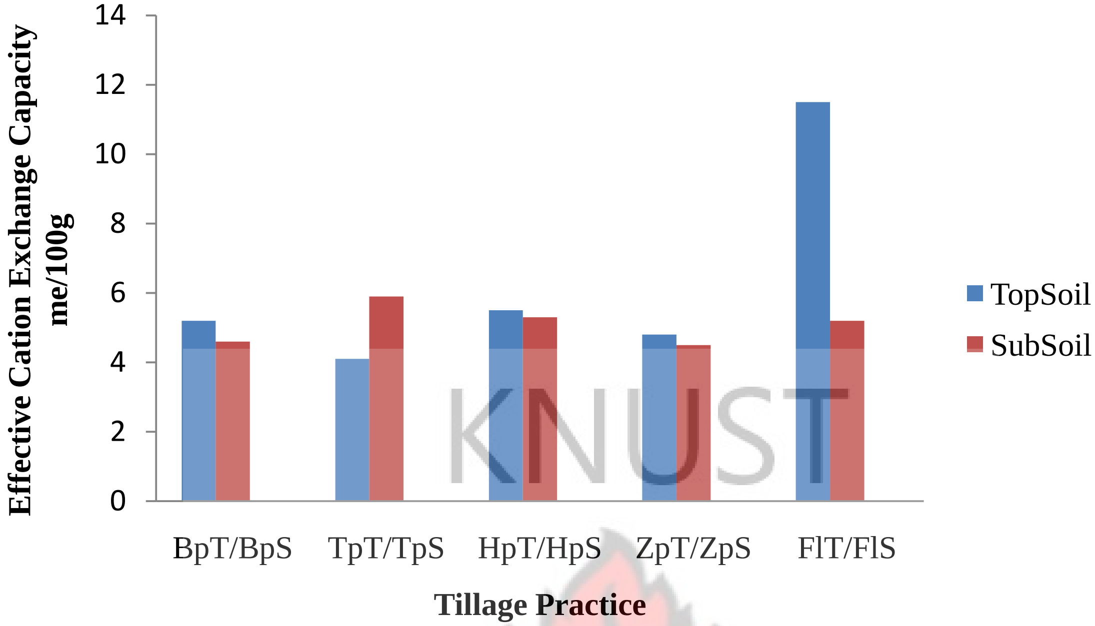


Fig. 16 Tillage Practices and Effective Cation Exchange Capacity

4.2.7 Tillage Practices and Nitrogen

The Figure 17 shows tillage practices and nitrogen content of the soil. There were no significant differences among the tillage practices $P > 0.05$, DMRT. Fallow land top and subsoil recorded the largest value of 0.06 %. Tractor plough subsoil recorded the least value of 0.01 %. It was observed that fallow land, zero tillage and bullock plough all recorded the same values for their top and sub soils. However, hand hoed and tractor plough lands showed small difference of 0.01 % between their top soils and sub soils.

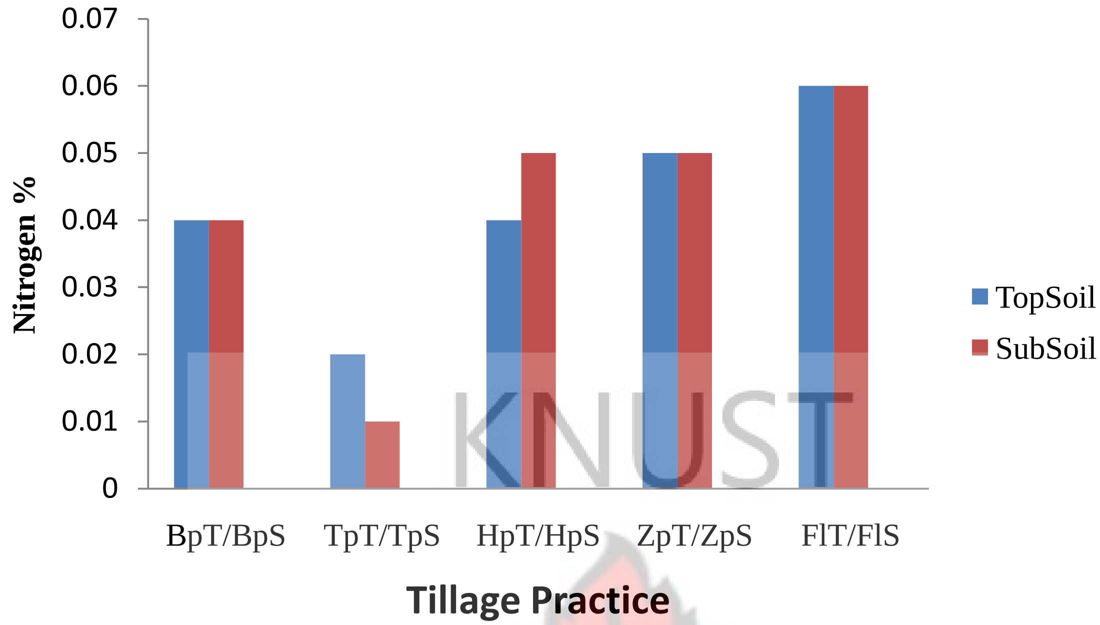


Fig. 17 Tillage Practices and Nitrogen

4.2.8 Tillage Practices and Available Phosphorus

Results did not indicate any significant differences $P > 0.05$, DMRT among the tillage practices. Tractor plough topsoil recorded the largest value of 22.0 ppm of available phosphorus whilst hand hoed gave the least value of 2.2 ppm. This was followed by zero tillage topsoil with a value of 14.4 ppm. The rest of the tillage practices recorded values below 5.0 ppm. The average available phosphorus content has been 6.1 ppm (Fig. 18).

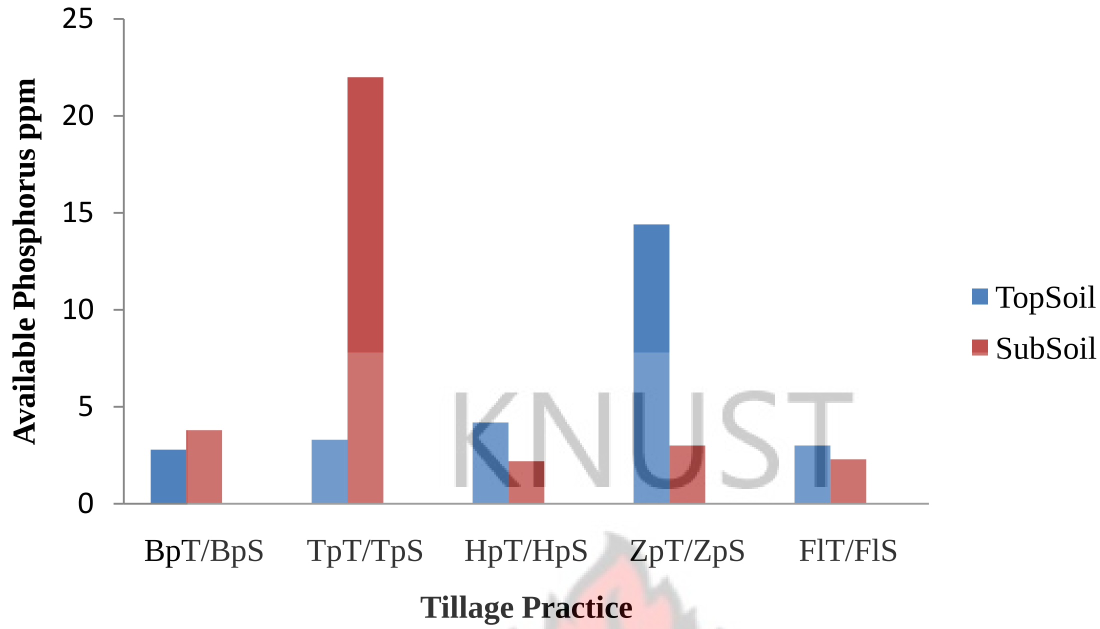


Fig. 18 Tillage Practices and Available Phosphorus

CHAPTER FIVE

DISCUSSION

5.2.1 Background Information of Respondents

The study showed that 23 % of the 120 respondents sampled were educated up to primary and secondary level whilst 77 % did not attend school. Ninety six per cent of the sampled population was engaged in agriculture in one form of the other. This confirms the information from the West Mamprusi District Assembly profile (WMDA, 2009) that the economic base of the district was agriculture with an average of 80 % of the economically active population engaged in one form or the other of it. The general low educational level of the respondents could be the reason why only few of them were engaged in government and non-governmental employment sectors.

5.2.2 Types of Land Tillage Practices in the District

The use of tractor was common probably because it was found to be faster and provided fine soil tilt as indicated by some respondents. Other reasons advanced by farmers for the use of this tillage practice had to do with land area. The larger the land area, the better the use of a tractor. Bullocks have become scarce of late whilst chemical usage is becoming prominent since it is less cumbersome and cheaper. Hand hoeing though was found to be the cheapest; it is cumbersome, slower and not practicable on large land area.

5.2.3 Knowledge of Farmers on Effect of Tillage Practices on Soil Fertility

Responses from the survey indicated that majority of the respondents did not know that their land preparation practices had effects on the nutrient status of the soil and for that matter soil fertility. This agrees with one of the rationale for the study which stated that majority of producers or farmers were ignorant on the effects of their land preparation practices on soil fertility.

5.2.4 Farmers Opinions on Tillage Effects on Soil Fertility

Though the survey showed lack of knowledge by farmers on the effect of their farming activities on the soil nutrients, they expressed varied opinions on effect of their tillage practices on soil fertility. It can be deduced from the survey that farmers had some thoughts about the effect of agro-chemicals usage on soil nutrients and that hand hoeing has very little effects. The main reason advanced by farmers why they thought agro-chemicals had more effects on soil fertility had to do with the fact that agro-chemicals usually kill living things such as pests and plants and so could kill other soil organisms which may be important for replenishing soil nutrient status.

5.2.5 Farmers Information About Organic Farming /Sustainable Agriculture and their Opinions on How to Protect the Environment to Maintain Soil Fertility

The survey showed that farmers had heard about sustainable agriculture/organic farming before. Farmers who practiced sustainable agriculture or organic farming during the past three years mentioned the followings as sustainable agriculture practices (1) use of poultry and farm yard manure (2) use of compost (3) crop rotation and crop residue. The probable reason why the use of these practices could be due to their inexpensive nature. The survey revealed that farmers' opinions on how to protect the environment and maintain soil fertility varied. Their opinions were (1) farmers must avoid farming near water bodies and practice crop rotation system of farming (2) avoidance of extensive use of chemicals during land preparation and adherence to the use of crop residues on lands (3) avoid deforestation by not practicing clear-cutting of trees and rather use fallow system of farming. The opinions and ideas of these respondents agree with Kevin and Lewis, (1995) who observed that human activities had exposed many parts of the natural environment to considerable risk. They indicated that the first human impact on the environment which is still prevalent is on vegetation where the use and misuse of fires is the order of the day. Deliberate burning is use to clear the land for agricultural purposes. Fires cause a reduction in natural vegetation; threaten wildlife, humans and property. Fires produce secondary problems associated with the clearance of vegetation such as soil erosion, flooding and wind erosion. Deforestation involves the deliberate removal of forest to create new agricultural lands. Deforestation and degradation of other vegetation, particularly near margins of deserts, have caused once fertile/vegetated lands to become barren in a process called desertification. They added that factors that contributed to the expansion of desert regions also included bad land management and poor farming techniques. Koetke (1993) indicated that depletion may occur through a variety of other effects, including over tillage which damages soil structure, over use of inputs such as synthetic fertilizers and herbicides, which leave residues build up that inhabit micro-organisms growth and result in salinisation.

5.2.6 Tillage Practices and Yield of Maize in Bags/Acre

This indicates that planting on no tilled land or soils is better than on hands hoed. Earlier studies on the effects of mechanized tillage systems on maize yield (Couper *et. al.*, 1979) showed that maize grain yields for six consecutive years were higher on no-till than ploughed plots. Organic matter content that has declined for decades by tillage practices affects soil property and fertility level and induces crop yield decline (Zougmore and Hosikawa, 2006). Franzluebber *et. al.*, (1995) indicated that reduced and particularly no-tillage (NT) practices minimize soil disturbance, increase soil organic matter and improve soil structure compared with conventionally ploughed soils. Christian and Bacon (1990) observed that the overall effects are usually an improvement in soil quality and decrease in pollution of surface waters by erosion. In many situations, zero, minimum and conservation tillage techniques have increased rather than decreased crop yields, often because of better germination and crop establishment. Even where yields are less with conventional tillage, the difference is usually small, and the savings in machinery, labour and fuel costs increase profit margins compared with conventional tillage. Though soil fertility parameters were generally low, they were higher in zero tillage as well as fallow land than the rest of the tillage practices which explains why zero tillage had better yield.

5.2.7 Tillage Practices and Bulk Density

This was however, contrary to observations by Rashidi and Keshavarzpour (2007) who indicated that conventional tillage practices modify soil structure by changing its physical properties such as bulk density, soil penetration resistance and soil moisture content. They emphasized that annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage method which leaves the soil intact. Reports have indicated contrasting results as to the effect of tillage on bulk density. Blevins *et al.* (1983a) reported that tillage had no effect on bulk density after 10 years of tillage treatments on a medium textured soil. Blevins *et al.* (1983b) found similar bulk density values with conventional and no-till system and smaller bulk density with chisel tillage on poorly drained soil. Ohiri and Ezumah (1990) stated that soil manipulation can change fertility status markedly and the changes may be manifested in good or poor performance of crops. In addition, tillage operations loosen, granulate, crush or compact soil structure, changing soil properties such as bulk density, pore size distribution and composition of the soil atmosphere that affect plant growth. Tillage loosens the soil structure and causes an immediate increase in the percentage of macrospores, resulting in lower bulk density and greater porosity (So *et al.*, 2009) which can benefit seedling establishment and crop growth (Sturz *et al.*,, 1997). Generally, converting from conventional tillage system to a conservation tillage system results in a higher bulk and a lower total porosity (Johnson-Maynard *et al.*, 2007) as macrospores are not created as is the case during ploughing. The seemingly no difference in the bulk density of the soils could be attributed to environmental conditions. This was reiterated by Ishaq *et al.*, (2002) who stated that the contradictory results of tillage effects on soil properties found in literature "may be due to differences in crop species, soil properties, climatic characteristics and their complex interactions". Therefore, it is necessary to examine the long-term effect of tillage at different locations and under various environmental and soil conditions so that more accurate generalizations can be made regarding the conditions required for sustainable tillage systems (Ishaq *et al*., 2002).

5.2.8 Tillage Practices and Particle Size Distribution

The results indicated that the soil texture of the area was generally sandy loam to loamy sand with sand, silt and clay content range of 29.2-83.4 %, 4.6- 62.8 % and 4.0- 12.0 % respectively depicting the generally low magnitude of soil fertility parameters (Table-2). The texture of the soil in the study area is generally sandy loam which accounts for about 20 %, loam which is 20 % with loamy sand and silt loam being 30 % each. These soils drain easily and as a result encourage leaching of nutrients. The clay content is abysmally low (Table-2) which accounts for the generally low cation exchange capacity of the soils. Ploughing causes the rapid break down of organic matter. The soil collapses and compacts, increasing erosion and reducing the number of soil organisms. The topsoil becomes susceptible to erosion and water runoff, so that after heavy rainfall a great deal of soil is lost. Little water is retained due to the textural type of the soil; leading to shallow and infertile soils which are no longer able to produce good yields. The cost of production also increases as the farmer needs to apply more fertilizer and use fuel to plough his land.

5.2.9 Tillage Practices, Organic Carbon and Organic Matter

Organic matter content in soil is directly proportional to organic carbon (OC) content. From the analysis, there were no significant differences between the tillage practices with regards to organic carbon. This observation however, appeared to be in contrast with Ball *et. al.*, (1997) who stated that organic matter content of soil varies drastically in response to differences in land use. Organic matter contents are often lowest in soils under intensive arable cultivation, as relatively little organic matter is returned to the soil after harvest. Compaction which occurs as a result of certain tillage practices apart from decreasing infiltration rate restricts root growth, decrease nutrient uptake rates and crop yields, and increase erosion, leading to transfer of nutrients and pesticides to surface water. It was expected that since fallow lands were lands that have not been disturbed for some time and as such should have high built up of organic matter, should have had more organic matter than the rest of the tillage practice. This was not revealed by this study. Most of the carbon (C) losses following soil disturbance such as tillage originate from the active and slow pools, which comprise the biologically defined soil organic pools described as active (labile), slow (partially labile) and passive (stable) (Jenkinson, 1990). Tisdale *et. al.,* (1993) indicated that tillage of the soil produces greater aeration, thus stimulating more microbial activity, and increases the rate of disappearance of soil organic carbon which is a direct measure of organic matter in the soil. This observation by Tisdale *et. al*., (1993) was not indicated by this research. It was expected that the study would indicate significant differences between the tillage practices with regards to organic carbon content with zero tillage recording appreciably more organic carbon content than the rest of the tillage practices to agree with Tisdale *et al.*, (1993) report. Tillage also results in partial aggregate destruction and concomitant organic matter loss (Wright and Hons, 2005). Zero or minimum tillage often also increases soil organic matter content, especially in the uppermost soil layers (Johnson, 1992). This observation again was not manifested. Chartres *et. al.,* (1992) reported that traditional farming practices such as burning, removal of stubbles and conventional tillage result in a decline in soil carbon. In contrast, reduce or no- tillage, residue retention, the use of green manure crops, pasture leys and application of organic materials result in an increase in soil carbon. Tillage practices that disrupt aggregates cause increased breakdown of SOM (Adu and Oades, 1978) and affect the constituent SOM fractions (Cambardella and Elliot, 1994). Conventional tillage systems result in SOC loss (Dalal and Mayer, 1986) and soil aggregate destruction (Tisdale and Oades, 1982) via exposure of physically protected SOM to microbial attack (Beare *et al.*, 1994). The differences obtained from this study as against what had been reported in the literature could be probably attributed to the fact that the tillage practices engaged by farmers in the study area were similar in all respect regarding inputs use, land preparation methods and land cultivation history and only differentiated by the method of tillage. This could be the possible reasons why the results did not indicate any significant differences though they could have been slight differences.

5.2.10 Tillage Practices, Total Exchangeable Bases and Effective Cation Exchange Capacity

Cation exchange capacity is enhanced by the presence of soil organic matter. The results indicated better organic matter content associated with FlT than the rest of the tillage practices. The higher the organic matter contents of the soil, the better its total exchangeable bases and for that matter its cation exchange capacity. Any process that will result in the volatilization of organic carbon and for that matter organic matter would also affect the soil cation exchange capacity. Tractor plough topsoil (TpT) and its corresponding subsoil showed the lowest content of total exchangeable bases. This was in agreement with Fullen and Catt (2004) who stated that ploughing exposes the soil organic carbon which is a determinant of soil organic matter to volatilization. They added that soil organic matter content is determined by the balance between inputs of plants, animal and microbial residues and losses by leaching and evaporation of soluble and volatile products of decomposition. Losses may also occur by soil erosion which is increased by ploughing as a result of exposure of topsoil. FlT has not been subjected to tillage practices for sometime which may explain why its total exchangeable bases as well as its effective cation exchange capacity was larger due to its better organic matter content. Simpson (1983) indicated that the humus fraction of organic matter in particular has very high cation exchange capacity and therefore able to retain nutrients such as base cations which are available for plant uptake. Buol *et al*., (1975) noted that soils with effective cation exchange capacity (ECEC) of 4 me/100g or less had limited ability to retain nutrient cations. Leinweber *et al.*, (1993) reported that soil organic matter contributes most of the cation exchange capacity of A horizons, even of mineral soils with small amount of soil organic matter. This probably explains why the Fallow land Topsoil (FlT) had more organic matter than the other tillage practices though not in magnitude that could be considered as significant as results indicated.

5.2.11 Tillage Practices and Total Nitrogen

Total nitrogen and organic matter contents are correlated and so the source of nitrogen is organic matter. This, Simpson (1983) stated that in addition to organic matter water retention properties, it is often added to soils as mulch to reduce water losses by evaporation and that it is an important source of essential plant nutrients, particularly nitrogen. There were no significant differences with regards to organic matter content between the tillage practices as the organic matter content of the soils of the study area were generally too low (0.2-1.2 %) as indicated by the CSIR-Soil Research Institute ranking as < 0.1, 0.1-0.2 and > 0.2 being low, moderate and high respectively. The tillage system can influence soil nitrogen availability due to its impact on soil organic carbon and nitrogen mineralization and subsequent plant nitrogen use or accumulation (Al-Kaisi and Licht, 2004). Compared with no-tillage, the conventional tillage system can significantly change mineralizable carbon and nitrogen pools (Woods and Schuman, 1988). However, a long term no-tillage system has potentially greater mineralizable carbon and nitrogen pools compared with conventional tillage (Doran, 1980). This scenario was however, not observed in this study as the proposed effect of tillage practices on nitrogen and organic matter content could not be indicated by the results of this research.

5.2.12 Tillage Practices and Available Phosphorus

This could probably be due to the fact that the various tillage practices had the same or similar crop cultivation history coupled with the fact that available phosphorus is not readily mobile in soil unlike the other soil nutrients such as potassium. This scenario was however, contrary to the observation on trials by Ausmane *et al.* (2000) and Maiksteniene (2000) who reported that loosening the soil in the form of tillage led to a decline in the available phosphorus content in the 10-25 cm layer without, however, ensuring a higher content in the upper 0-10 cm layer. Ortiz-Monasterio *et et.*, (2002) indicated that as the nitrogen availability is affected by the tillage system, phosphorus availability can equally be affected, leading to a phosphorus deficiency in many cropping systems. Many soils have large reserves of total phosphorus, but low levels of available phosphorus. Though tillage affected total nitrogen where fallow land had better nitrogen content than tractor ploughed land, available phosphorus had not been affected as observed by Ortiz-Monasterio et al., (2002).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The current study showed that agricultural land tillage practices have impact on soil nutrients status and farmers unfortunately had little knowledge about this fact. The nutrients status of the soils were generally low with only few being moderate as ranked by CSIR-Soil Research Institute. The effects of tillage practices were more prominent in the chemical properties of the soil than the physical properties. Organic matter which is one of the most important determinant of soil nutrients and for that matter soil fertility was abysmally and extremely low in the tillage practices except in the fallow lands which showed a low figure as ranked by CSIR-Soil Research Institute. Cation exchange capacity (C.E.C.) particularly exchangeable Potassium (K) and Calcium (Ca) were low to moderate. Total exchangeable bases and effective cation exchange capacity were also low which accounts for the general low productivity of the soils in the study area as it is usually manifested in the yields. It is however, important to note that in designing sustainable agricultural production systems, it is necessary to give due consideration to the characteristics of various resources used in production, the ways they are managed or manipulated in the production process and the technologies and practices which render the resultant production system unsustainable. Unsustainability results when impacts of practices and technologies used are economically not feasible and sometimes also culturally unacceptable. In addition to selection methods for manipulation of resources and use of practices and technologies which ensure sustainability, there is a need to ensure that other sectoral activities do not render the farming systems unsustainable. At the same time measures must be taken to ensure that various accelerators of agricultural development and factors which ensure enabling environment for agricultural production for majority of farmers are present.

6.2 Recommendation

Stakeholders in environmental management and protection should assist in designing sustainable farming systems guided by laid down recommended principles. These principles or objectives should be aimed at namely: a) maintenance or enhancement of farm productivity in the long term, b) amelioration, minimization or avoidance of adverse impacts on natural resource base for agriculture and associated ecosystem, c) minimization of residues from chemicals used in agriculture or adverse effects of practices, d) maximization of net social benefits of agriculture when positive and negative effects are considered and making such choices among alternatives as to maximize benefits by using certain production systems and practices; and e) rendering farming systems sufficiently flexible to manage risks associated with vagaries of climate and markets. It is recommended that further studies on this research focusing on several different locations may prove worthwhile. For the interim, farmers should be advised to practice fallow system of farming to help maintain soil fertility. They should be encouraged to use crop residues in their farming practices; in other words they should be encouraged to avoid slashing and burning during land preparation and instead incorporate residues into soil. Practice of crop rotation should be encouraged. District assembly should establish environmental unit or department if it does not have one to continue to educate farmers on environmental degradation, climate change issues and safety use of agro-chemicals. It is also recommended that NGOs and other relevant stake holders in environmental management should focus more on land degradation and management issues so as to be agriculture sustainable, ensure food security for the growing human population.

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APPENDICES

APPENDIX 1

ANOVA TABLES

Tillage Practices and Yield of Maize

Source of Variation	Degree of Freedom	Sum of Squares	Mean Value	F-Value	Probability
Block	2	2.265	1.1325	1.30	
Treatment	9	40.2007	4.4667	5.14	0.002*
Residual	18	15.6438	0.8691		
Total	29	58.1095			

***Significant at 5% (P=0.05)**

Tillage Practices and Mean Bulk Density

Source of Variation	Degree of Freedom	Sum of Squares	Mean Value	F-Value	Probability
Block	2	0.005307	0.002653	0.27	
Treatment	9	0.076253	0.008473	0.86	0.573NS
Residual	18	0.176827			
Total	29	0.258387			

NS-Not Significant at 5% (P=0.05)

Tillage Practices and Total Exchangeable Bases

Source of Variation	Degree of Freedom	Sum of Squares	Mean Value	F-Value	Probability
Block	2	4.811	2.405	0.93	
Treatment	9	117.115	13.013	5.04	0.002*
Residual	18	46.499	2.583		
Total	29	168.425			

***Significant at 5% (P=0.05)**

Tillage Practices and Effective Cation Exchange Capacity

Source of Variation	Degree of Freedom	Sum of Squares	Mean Value	F-Value	Probability
Block	2	5.128	2.564	1.01	
Treatment	9	122.853	13.650	5.36	0.001*
Residual	18	45.831	2.546		
Total	29	173.812			

***Significant at 5% (P=0.05)**

Tillage Practices and Total Nitrogen

Source of Variation	Degree of Freedom	Sum of Squares	Mean Value	F-Value	Probability
Block	2	0.0061267	0.0030633	5.95	
Treatment	9	0.0061467	0.0006830	1.33	0.291NS
Residual	18	0.0092733	0.0005152		
Total	29	0.0215467			

NS-Not Significant at 5% (P=0.05)

Tillage Practices and Available Phosphorus

Source of Variation	Degree of Freedom	Sum of Squares	Mean Value	F-Value	Probability
Block	2	637.0	318.5	2.28	
Treatment	9	1201.4	133.5	0.95	0.505NS
Residual	18	2516.7	139.8		
Total	29	4355.2			

NS-Not Significant at 5% (P=0.05)

Tillage Practices and Organic Carbon

Source of Variation	Degree of Freedom	Sum of Squares	Mean Value	F-Value	Probability
Block	2	0.58226	0.29113	4.95	
Treatment	9	0.80160	0.08907	1.51	0.217NS
Residual	18	1.05921			
Total	29	2.44307			

NS-Significant at 5% (P=0.05)

Tillage Practices and Organic Matter

Source of Variation	Degree of Freedom	Sum of Squares	Mean Value	F-Value	Probability
Block	2	1.7236	0.8618	4.93	
Treatment	9	2.4035	0.2671	1.53	0.212NS
Residual	18	3.1465	0.1748		
Total	29	7.2736			

NS-Not Significant at 5% (P=0.05)

APPENDIX 2

CSIR SOIL NUTRIENT RANKING

Soil nutrient (mineral) content

Nutrient	Rank/Grade
Soil pH (Distilled Water Method)	
< 5.0	Very Acidic
5.0-5.5	Acidic
5.5-6.0	Moderately Acidic
6.1-6.5	Slightly Acidic
6.6-7.0	Neutral
7.1-7.5	Slightly Alkaline
7.6-8.5	Alkaline
>8.5	Very Alkaline
Organic Matter (%)	
< 1.5	Low
1.6-3.0	Moderate
3.0	High
Nitrogen (%)	
< 0.1	Low
0.1-0.2	Moderate
>0.2	High

From Soil Research Institute (CSIR)

Nutrient	Rank/Grade
Phosphorus, P (ppm)-Bray's No.1	
< 10	Low
10-20	Moderate
>20	High
Potassium, K (ppm)	
< 50	Low
50-100	Moderate
>100	High
Calcium, Ca (cmol(+) Kg^{-1}) / Mg = 0.25 Ca	
< 5	Low
5-10	Moderate
>10	High
Exchangeable Potassium (cmol (+) Kg^{-1})	
< 0.2	Low
0.2 – 0.4	Moderate
>0.4	High
ECEC (cmol (+) Kg^{-1})	
< 10	Low
10-20	Moderate
>20	High

From Soil Research Institute (CSIR)

APPENDIX 3

SURVEY QUESTIONNAIRES

Questionnaire on Agricultural Tillage Practices on Soil Fertility: A Case Study of the West Mamprusi District of the Northern Region (Tick or Write Where Appropriate)

A. Personal Background

01. What is your name ……………………………………………………….

02. How old are you ………………………………………………………...

03. Sex A. Male ☐

B. Female ☐

04. Marital status A. Married ☐

B. Single ☐

C. Devoiced ☐

D. Separated ☐

E. Others……………………………………………

05. Do you have children?

A. Yes ☐

B. No ☐

C. Don't know ☐

D. Others…………………………………………

06. If yes, how many children do you have?

A. 1-2 ☐

B. 3-4 ☐

C. 5-6 ☐

D. Others (Specify) ………………………………

07. What is the sex of your children and how many each?

A. Male ………………………..

B. Female ………………………..

08. How many of them are in school?

A. 1 ☐

B. 2 ☐

C. 3 ☐

D. Others (Specify)…………………………………

B. Category of Respondent

A. Farmer only ☐

B. Opinion leader only ☐

C. Chief only ☐

D. Farmer and opinion leader ☐

E. Chief and farmer ☐

F. Others (Specify) ………………………………

C. Educational Background

09. Have you ever attended school?

A. Yes ☐

B. No ☐

C. Others (Specify) ………………………………….

If **No**, skip question 10

10. What is your highest level of education?

A. Primary ☐

B. Secondary ☐

C. Tertiary ☐

Others (Specify) ………………………………..

D. Occupation

11. What type of work do you do?

A. Government ☐

B. Non-governmental (NGO) ☐

C. Farming ☐

D. Others (Specify) ………………………………….

(Multiple choices)

E. **Land Tillage Practices**

12. What type of crops do you cultivate?

A. Maize ☐

B. Rice ☐

C. Groundnuts ☐

D. Others (Specify)…………………………..

(Multiple choices)

13. How many acres do you cultivate?

A. 1 ☐

B. 2 ☐

C. 3 ☐

D. Others (Specify)………………………

14. What is your yield per acre?

A. 2 bags ☐

B. 3 bags ☐

C. 5 bags ☐

D. Others (Specify)…………………………

15. How do you normally prepare your land for the cultivation of your crops?

A. Slashing and burning ☐

B. Clear-cutting, slashing and burning ☐

C. Use of agro-chemicals to kill weeds ☐

D. Others (Specify)……………………………..

16. What do you normally use to plough your land before planting your crops?

A. Tractor ploughing and planting ☐

B. Bullock ploughing and planting ☐

C. Use of agro-chemical to kill weeds and planting ☐

D. Use of hoe and planting ☐

17. In your observation, does the land tillage method that you practice have effect on yield?

A. Yes ☐

B. No ☐

If **yes,** answer 18 if **no** proceed to 19.

18. Which land tillage method has more yields?

A. Tractor plough ☐

B. Bullock plough ☐

C. Use of agro-chemicals (zero tillage) ☐

D. Hand hoeing ☐

18. How long have you used this land tillage method?

A. 1-2yrs ☐

B. 3-4yrs ☐

C. 5-6yrs ☐

D. Others (Specify) ……………………………..

19. Is the way you till/prepare your land now for the cultivation of your crops the same as the way your fore fathers used to do?

A. Yes ☐

B. No ☐

C. Don't know ☐

D. Others (Specify) ………………………………..

If **no** Explain…………………………………………………………..

F. Knowledge on the Environment/ Soil Fertility and Effect of Land Tillage Practices on Soil Fertility

20. Have you ever heard anything / something bad said about the environment/ soil fertility?

A. Yes ☐

B. No ☐

21. In your opinion, which of the following do you think have been said about the environment/ soil fertility?

A. Depletion of soil nutrients/ loss of soil fertility ☐

B. Pollution of the air / water bodies or environment ☐

C. Extinction of species/ death of organisms ☐

D. Others (Specify) ………………………………..

22. Do you think your land tillage practices / methods have an effect on the soil fertility?

A. Yes ☐

B. No ☐

24. Which of the following practices / methods of land tillage practices do you think will have an effect on the soil fertility/environment?

A. Tractor ploughing and planting ☐

B. Bullock ploughing and planting ☐

C. Use of agro-chemical to kill weeds and planting ☐

D. Use of hoe and planting ☐

G. Knowledge on Sustainable Agriculture

25. How do you maintain the fertility of your farm?

A. Use of inorganic fertilizers / NPK and Sulphate of Ammonia ☐

B. Use of compost ☐

C. Use of farm yard manure / poultry droppings ☐

D. Others (Specify) …………………………

26. In your own observation, is there any known difference on the impact of soil fertility with the use of organic or inorganic fertilizer?

A. yes ☐

B. No ☐

If **yes,** answer 27 if **no** proceed to 28

27. Which one?

A. Organic ☐

B. Inorganic ☐

28. How many bags of NPK do you normally apply per acre?

☐

A. 1

B. 2

C. 3

D. Others (Specify)………………………..

29. How many bags of Ammonia do you normally apply per acre?

A. 1

B. 2

C. 3

D. Others (Specify)…………………….

30. How do you control weeds on your farm?

A. Hand weeding

B. Use of agro-chemicals

C. Use of weeds resistant varieties

D. Others (Specify) …………………………….

31. Which of the following have you practiced on your farm for the past two years?

A. Crop rotation

B. Mixed cropping

C. Bush fallow

D. Mono cropping

E. Others (Specify) …………………………….

32. Have you heard about Organic Farming / Sustainable Agriculture?

A. Yes

B. No

If **yes,** answer question 29, if **No,** proceed to question 30.

33. What is your opinion/level of knowledge on Sustainable Agriculture?

A. Good ☐

B. Excellent ☐

C. Bad ☐

D. Others (Specify) ……………………………

H. Inputs from Farmers on How to Maintain Soil Fertility

34. What agricultural practices do you think you/we can do to protect the environment from degradation and maintain soil fertility?

A. Practice crop rotation/use of crop residues ☐

B. Use compost in our farming activities ☐

C. Make use of poultry and farm yard manures ☐

D. Others (Specify) ………………………

(Multiple choices)

35. Which of the following in your opinion do you think can assist ensure that the environment is protected?

A. Avoid deforestation by not practicing clear-cut Methods of land preparation ☐

B. Avoid the extensive use of chemicals in land Preparation and in the control of weeds ☐

C. Avoid farming near water bodies ☐

D. Others (Specify) ………………………

(Multiple choices)

THANK YOU VERY MUCH FOR YOUR TIME!