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Effect of tillage practices on soil fertility

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Abstract

Food security depends on sustainable agriculture. Sustainability hinges on the efficient and judicious use of land and soil resources. This study 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 (FlS). The study consisted of two components namely: a survey and soil nutrient analysis. ANOVA was used to analyze the results using the GENSTAT statistical package whilst treatment means were compared using Duncan's Multiple Range Test (DMRT) at P=0.05. Survey indicated that 80 % of the respondents did not know of the effects of their tillage practices on soil fertility. Forty four percent, 33 % and 23 % of them indicated use of fallow system, crop residues and 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 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).

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Introduction

There exist evidence that soil tillage practices have adverse effects on soil fertility. This evidence have been presented here in the form of reviews and reports alluding to the effect of tillage on soil fertility. The evidence also needed to be confirmed at the study area as locations differ with regards to soil fertility trends. Information on this subject was gathered from users of the land with particular emphasis on type of tillage methods employed by land users, ideas of land users on effects of activities on soil nutrients depletion, nutrient content analysis in the laboratory and how to prevent nutrient loss on soils to ensure agricultural sustainability have been placed under introduction.

The processes involved in the collection of information and data management and analysis can be found under materials and methods. Confirmation of findings or otherwise with support from reviews and reports is categorized under results and discussions. Information presented in this write up is based on the responses from land users which is presented in the form of pie charts whiles nutrient content analysis is presented in the form of bar charts and placed after acknowledgement.

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).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).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).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. 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).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).Since cation exchange capacity (C.E.C) is enhance by the presence of soil organic matter, 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. Losses may also occur by soil erosion which is increased by ploughing as a result of exposure of topsoil (Fullen and Catt, 2004). Ball *et. al.,* (1997) stated that organic matter 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. 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. 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.Ausmane *et al.* (2000) and Maiksteniene (2000) 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. Observation made by Kevin and Lewis, (1995) was that human activities had exposed many parts of the natural environment to considerable risk and 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 purpose and that factors that contributed to the expansion of desert regions also included bad land management and poor farming techniques.

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. Tillage practices have adverse effects on soil fertility as indicated by various reports mentioned above. However, most works around tillage practices and soil fertility focused on nutrient content analysis with little emphasis on the perception of the users of the land on this subject matter. The users of the land appear to be ignorant on their farming activities on the fertility of the soil. The aims of the study were to assess tillage methods employed by farmers, determine soil physical and chemical properties of sampled soil, evaluate nutrient content of sampled soil, assess farmers perceptions on land use and recommend soil fertility improvement practices.The objective of this research therefore, was to assess the effect of tillage practices on soil fertility.

Materials and methods

Experimental Location

The study was carried out in the West Mamprusi District of the Northern Region of Ghana. It is located roughly within longitudes 0°35'W and 1°45'W and Latitude 9°55'N and 10°35'N. 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. 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). The soils support crops such as yams, maize, cowpea, soybean, millet, groundnuts, sorghum and cassava. Farmers in the 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 (Brammer, 1962).

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 about the environment as well as the effect of 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.

Survey

Questionnaires were used as a data collection technique to primarily identify the type of land tillage practices in selected areas and knowledge of farmers on effect of their land tillage practices on soil fertility. A total of one hundred and twenty questionnaires were administered in ten communities, with twelve questionnaires in each community.

Field Work

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 locations in the district namely: Wungu, Kparigu and Wulugu.Sixty 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.

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.

Data and Analysis

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

Results and discussion

Survey

Types of Land Tillage Practices in the 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. 1).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.

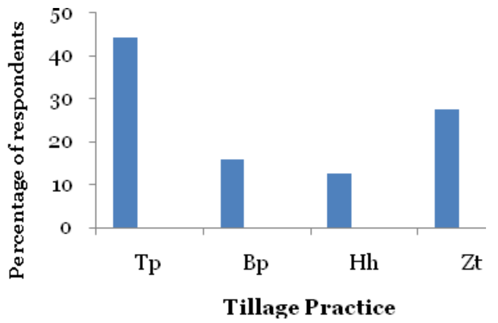

Fig. 1. Types of Tillage Practices (Bp=Bullock plough Tp=Tractor plough Hh=Hands hoeing Zt= Zero tillage).

Knowledge of Farmers on Effect of Tillage Practices on Soil Fertility

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. 2). 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.

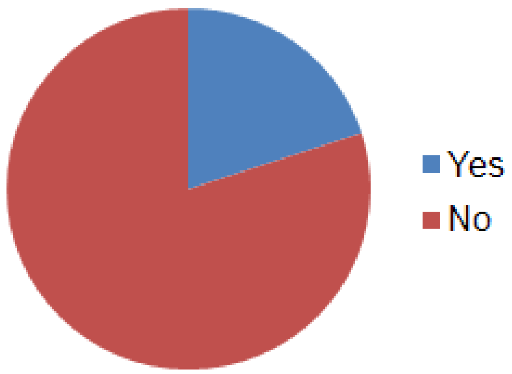

Fig.2. Knowledge of Effect of tillage on Soil Fertility.

Farmers Information about Organic Farming /Sustainable Agriculture and 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. 3). 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. 4). These represented 37 %, 21 % and 42 % respectively. 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. These represented 23 %, 33 % and 44 % respectively (Fig. 8). Farmers 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 indicating 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 and factors that contributed to the expansion of desert regions also included bad land management and poor farming techniques.

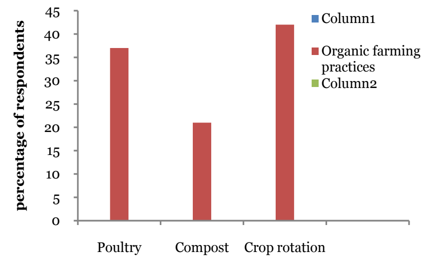

Fig.3. Organic Farming Practices by Farmers.

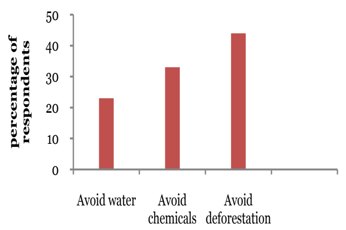

Fig.4. Opinions on Maintenance of Soil Fertility.

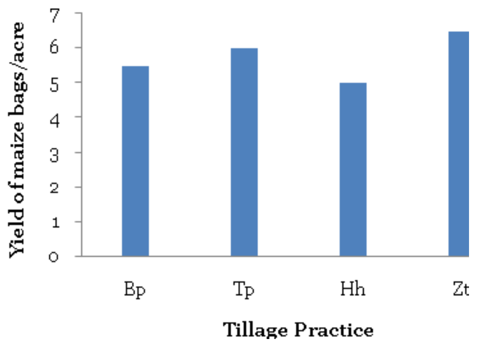

Fig.5. Tillage Practices and Yield of Maize in Bags/Acre.

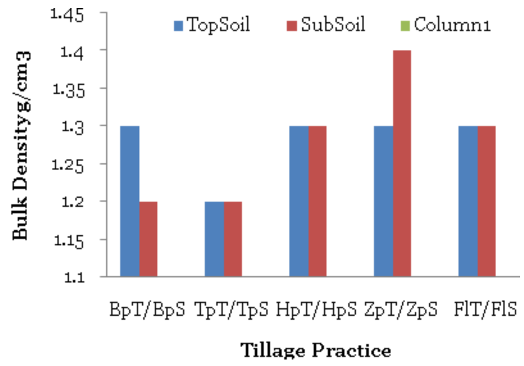

Fig. 6. Tillage Practices and Mean Bulk Density (BpT=Bullock plough topsoil) (BpS=Bullock plough subsoil) (TpT=Tractor plough topsoil) (TpS=Tractor plough subsoil) (HpT=Hand plough topsoil) (HpS=Hand plough subsoil) (ZpT=Zero tillage topsoil) (ZpS=Zero tillage topsoil) (ZpS=Zero tillage subsoil) (FlT=Fallow land topsoil) FiS=Fallow land subsoil).

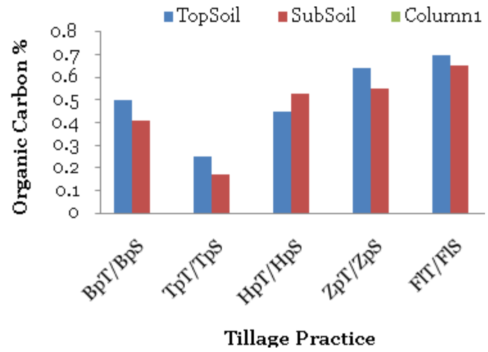

Fig.7. Tillage Practices and Organic Carbon.

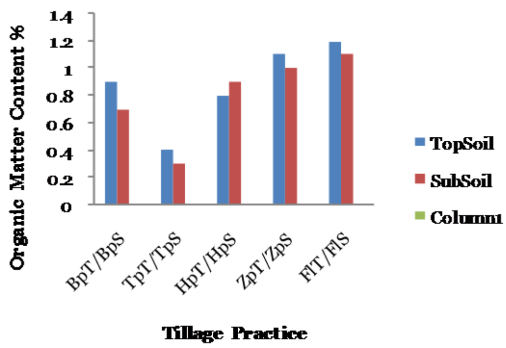

Fig.8. Tillage practices and Organic Matter.

Field Work

Tillage Practices and Yield of Maize in Bags/Acre

Fig. 5indicates 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). 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).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.

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 (Fig. 6). 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. 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.

Tillage Practices, Organic Carbon and Organic Matter

Fig. 7 and 8 show percentage organic carbon and organic matter contents 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 %. Fallow land topsoil contained the largest organic matter content of 1.2 % whilst tractor plough subsoil recorded the least of 0.2 %. Organic matter content in soil is directly proportional to organic carbon (OC) content. 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. 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 practices. 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. 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. 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.

Tillage Practices, Total Exchangeable Bases and Effective Cation Exchange Capacity

Fig. 9 and 10 show exchangeable bases and effective cation exchange capacity (E.C.E.C).There were significant differences $P< 0.05$ DMRT with regards to fallow land and the 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 and 11.5 me/100g with the least value of 3.9 me/100g and 4.1 me/100g recorded by tractor plough topsoil. 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. 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 some time and may explain why its total exchangeable bases as well as effectivecation 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. 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.

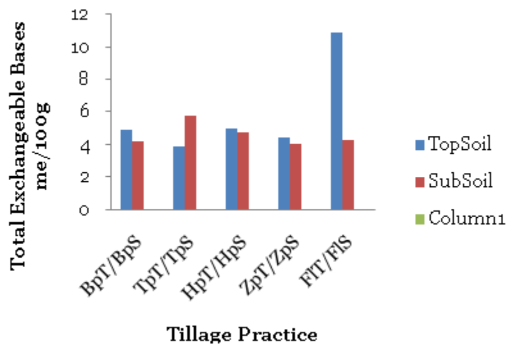

Fig.9. Tillage Practices and Total Exchangeable Bases.

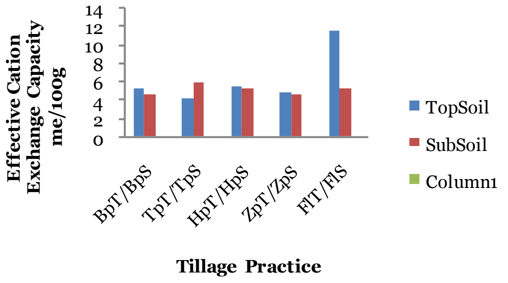

Fig.10. Tillage Practices and Effective Cation Exchange Capacity.

Tillage Practices and Total Nitrogen

Fig. 11 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. 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.

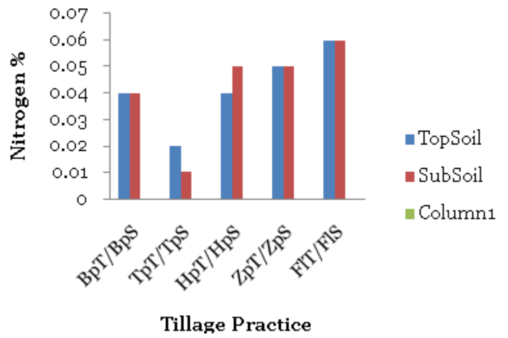

Fig.11. Tillage Practices and Nitrogen.

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. (Fig. 12).This could probably be because the various tillage practices had the same or similar crop cultivation history and also because 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.

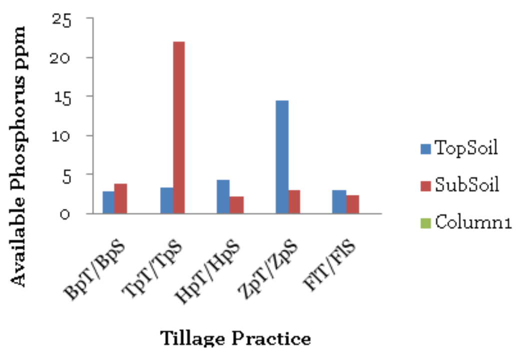

Fig.12. Tillage Practices and Available Phosphorus.

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