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EFFECT OF INITIAL LAND PREPARATION METHODS ON SELECTED SOIL PHYSICAL PROPERTIES IN AFRAM PLAINS, GHANA

BY

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(MACHINE SYSTEMS OPTION)

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Declaration

I hereby declare that with the exception of references to other people's work which have duly been acknowledged, this compilation is the result of my own research work and no part of it has been presented for another degree in this University or elsewhere.

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I hereby declare that the preparation of this project was supervised in accordance with the guidelines of the supervision of Thesis work laid down by the University of Ghana.

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Abstract

The objective of the study was to determine the most appropriate methods of initial land preparations in Afram Plains based on their effect on selected soil physical properties such as dry bulk density, porosity, hydraulic conductivity and available water content. The study also sought to estimate the cost of preparing farm lands in the Afram Plains.

The study was conducted in Odumesua in the Afram Plains District sampling soil from fields prepared with three identified and categorized systems of land preparations. These were Slash and Burnt cleared land with no-tillage (SBNT), manually cleared land with conventional tillage (MCT) and bulldozed land with conventional tillage (BCT). The soil properties were determined at 0-40cm depths at intervals of 10 cm for analysis. Financial cost of these land preparation methods was also estimated from machinery input cost derivatives and information gathered from local farmers.

Dry bulk density, porosity and hydraulic conductivity were significantly (at $p \leq 0.005$ level) affected by the land preparations methods. At different depths of sampling, hydraulic conductivity was not significantly (at $p \leq 0.005$ level) affected. However, available water content was not significantly affected by both factors (land preparation methods and depth of sampling). Dry bulk density at 1.5g/cm^3 reduced by 3% and 16% in MCT and BCT respectively compared with the UNCULTIVATED and SBNT. The results showed that agricultural lands prepared by bulldozing or stumps excavation and conventional tillage operations (BCT) was most appropriate using fertile agricultural soil indicators of soil physical properties. The results also indicated that it costs three times more in preparing lands employing heavy tractors like the bulldozer compared to the traditional methods of using human labour with simple tools.

Dedication

This thesis is dedicated to my mother, Doreen Williams, grandmother, Esther Odartei and my entire family for their unflinching support and motivation in my life through Christ's provisions;

Can a woman's tender care

Cease toward the child she bare?

Yes she may forgetful be;

Yet will I remember thee (Methodist Hymnal 432)

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List of Abbreviations

AWC- Available water Content

A - cross sectional area of soil sample core

a - cross-sectional area of stand pipe

BCT- Bulldozed land with tillage operations

L/hr- Litre of Fuel consumed per hour

FC- Field Capacity

C_{Fuel} – Cost of fuel (diesel) per litre in cedis

C_{Har}- Cost of harrowing a hectare of field in cedis

C_{Pl}- Cost of ploughing a hectare of field in cedis

$C_{bulldozing}$- Cost of bulldozing a hectare of field in cedis

H_1 - height of water in standpipe before drainage

H_2 - height of water in standpipe after drainage

K_{sat} – saturated soil hydraulic conductivity (cm/hr)

L - soil sample height within the core

MCT – Manually Cleared land with tillage operations

M_s - the mass of solid,

P% - Profit percent margin

PWP – Permanent Wilting Point

R_x - Relativity index for calculating farm machinery input cost of operation

SBNT – Slash and burnt clearing with no machine tillage operation

t_2-t_1 - change in time during water drainage within standpipe

T_{opr} - operational hours of work

UNCULTIVATED - land in its initial virgin conditions without any form of tillage

V_a - the volume of air,

V_w -the volume of water,

V_s - the volume of solid

V_t.- total volume

$\boldsymbol{w}_{ws}$ - weight of pressurised wet soil sample,

$\boldsymbol{w}_{ds}$ - weight of dried soil sample

$\boldsymbol{w}_{ec}$ - weight of empty can.

ρ_b – soil dry bulk density (g/cm^3)

ρ_s – Soil Particle density ≈ 2.65g/cm^3

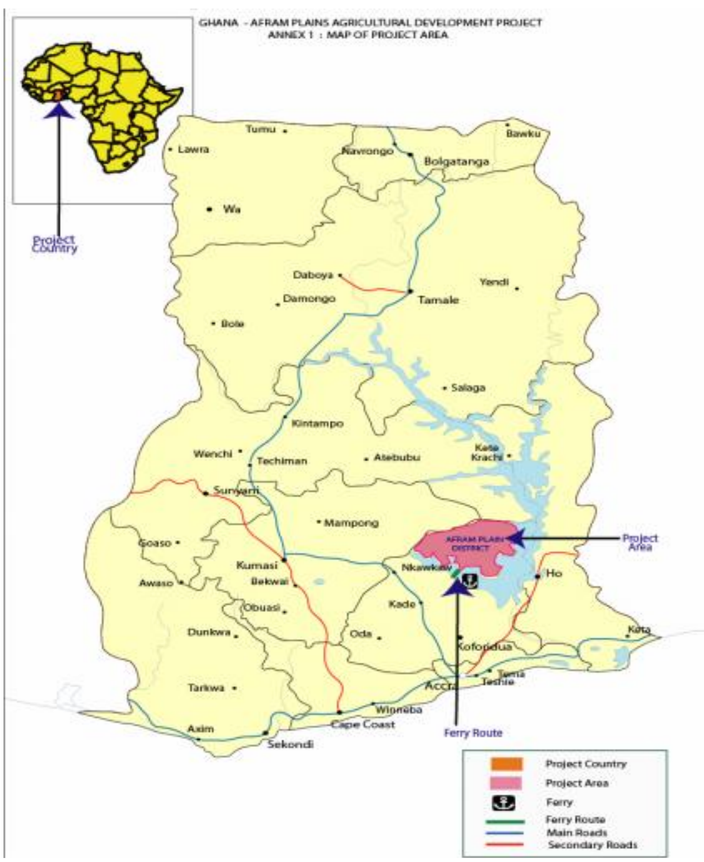
θ_g - gravimetric water content dry basis,

CHAPTER ONE

1.0 Introduction

1.1 Background to the Study

Ghana is an agrarian nation: this is proved by the fact that about 60% of the workforce of the country is involved in agriculture (MOFA, 2013). Ghana's agriculture contributes to over 30% (Second only to the Service industry) of the Gross Domestic Product (GDP), (SRID-MOFA, 2013). Ghana's agricultural potential has however been limited due to small scale peasant farming across major farming communities including the Afram Plains and the low level of mechanized farm systems (ADB, 2006).



(Source: ADB, 2006)

Figure 1: Location Map of Afram Plains in Ghana

Afram Plains is a farming community in Ghana located in the Kwahu-North Districts of the Eastern Region (figure 1). It has forest savannah transition vegetation and covers a total arable land area of about 523,260 hectares with less than 30% under cultivation (ADB, 2006).

The District has generally low lying lands that rise from 60 metres to 140 metres above sea level. During the rainy season months of April to November, mean monthly relative humidity ranges between 81.6% and 71.6% (MOFA, 2012). Annual rainfall ranges between 1200 mm and 1300 mm (Dietrich, 2008) . Soil type classified as Haplic luvisols (Food and Agricultural Organisation (FAO, 2007) constitute over 40% of the land area and belong to the Ejura Series (MOFA, 2012). With minor exceptions, the soils of the Afram Plains are fertile and suited to a wide variety of crops (MOFA, 2013). Major crops grown in this community includes yam, cassava, bananas, plantain, maize, groundnuts and many different vegetables (MOFA, 2013).

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 (Andrews *et al.*, 2004). Sustenance of high growth rates depends primarily on productive soils.

The quality of soil for plant growth is indirectly profound on the physical properties of these soils since the movement of air and water which strongly dictates biological and chemical interactions (properties) within the soils is also largely dependent on available pore spaces between soil particles which in turn is essentially affected also by the structure and texture of soils. Texture is the proportion of sand, silt and clay in the soil.

High crop productivity and sustainability depend on such soil potentials, among others and hence land clearing, which is the first major step in crop husbandry, must be handled with care (Mbagwu, 2008). Land preparation methods influence soil functions through their effects on soils qualities.

The capacity of a soil to function depends upon its inherent properties, which depend on its genesis and the dynamic changes in these properties which are the functions of the management systems (Gajri *et al.*, 2002). Soil management options including land preparation methods affect these properties and processes differently. The success of seed sowing, germination and consequent seedling growth depends on many factors of which the quality of land or soil preparation is vital. Land preparation involves the conditioning of land through clearing, tilling and field leveling activities to make it suitable for crop establishment.

Undisturbed soils in most vegetative communities where land preparation is done by traditional methods where little or no mechanical implements are employed see a rather more likely productivity of it soils. However, their productivity is constrained by their physical and hydrological properties, impeded by land preparation methods. Thus, the need for alternative technologies to these traditional methods is paramount. Despite a concerted effort during the last two decades to develop improved technologies for the soils, land preparation for agricultural productivity and sustainability remains a major challenge (Teklu, 2005).

Good soil aggregation is required for better water and nutrient movement through the soil (Arshad *et al.*, 1999) and compact soils restrict these movements due to the employment of bad mechanical methods in the land preparation process.

Research into appropriate bush clearing and tillage for environmental conservation in the tropics (Ojeniyi, 2010) showed that field crop production initiated by land clearing and soil cultivation, when improperly done could lead to loss of productive top soil. Again, (Ojeniyi, 2010) stated that traditional land preparation with hoes and machetes poses little or no adverse effects; mechanized methods with bulldozers cause the removal of top soil and organic matter making the soil prone to degradation. In order to conserve productivity of the soils, stumping is generally not done and this causes least soil disturbance and minimum erosion and conserves more water as is the situation in traditional land preparations. Finally it also indicated the indispensability of mechanical land clearing methods for increased land productivity and the need to experiment and adopt minimum clearing and tillage methods to avoid the removal of the top soil in land preparation.

Mechanised land preparation including tillage has therefore become an option for most farmers even at current low levels of mechanisation in effectively expanding farm lands whiles attempting to limit soil disturbance as a result.

Although the Afram Plains and other many farming communities of Ghana potentially have the capacity to yield greater food sufficiency for the country, a plethora of drawbacks besets it. This is enumerated in the Medium Term Agriculture Sector Investment Plan (METASIP) of the Food and Agriculture Sector Development Policy (FASDEP II) of the Ministry of Food and Agriculture, (MOFA, 2002). The two major main setbacks identified were the lack of agricultural mechanization in terms of machinery and the inappropriate methods of farmland development thereby leaving soils with poor nutrition and myriads of tree stumps. Whereas the former continues to receive some form of attention, the latter has limited attention, let alone the needed research into effectively preparing lands and their impact on soil productivity.

A prior enquiry into land preparation methods in Afram plains revealed three main ways by which the farm lands were prepared for cropping during my visitation. These methods were categorized according to (a) mode or process of clearing green cover or bushes from the surface of the top soil and (b) the tillage operations and activities carried out by these local farmers. These methods were named as follows for the purposes of this study:

a. Slash and Burn Clearing with no-tillage (SBNT)
b. Manual Clearing with tillage (MCT)
c. Bulldozed Clearing with tillage (BCT)

Most farmers who practice subsistence farming use the SBNT method to prepare their farmlands. In this method, one to three farmers (workers/labourers) usually start by clearing spaces (weeds) in-between the trees and shrubs on the farmland they want to develop with hoes and cutlasses. The land area is usually about 0.6 of a hectare. They then peel away the barks of the trees or shrubs close to the base and then set fire around the peeled areas. The fire destroys the phloem and xylem systems of the trees thereby killing it. In other instances, chemicals are sprayed on the trees rather than burning to kill or destroy them. They then use the dead trees as stakes to cultivate yam in the first season of farming. By the next season, the dead trees that were used as stakes would be very hollow and weak, and can even fall off just by a gentle push. The farmers therefore clear those dead trees manually or by employing the services of a tractor in ridding the farmland of trees and their stumps. The farmland apparently becomes “ploughable” by a tractor and consequent cropping is carried on the land.

In the manual method (MCT), the farmer who can afford employs the services of labourers (usually 5 – 7 workers) who would clear the land of trees and shrubs using rudimentary tools as mattocks, pickaxes, machetes/cutlasses and small machines like the chain saw. Large trees with base girth diameter of two to three square meters are however left on the farm site because these are difficult to pull down. The land can then be disc ploughed once and sometimes harrowed for planting to be done.

The bulldozed (BCT) method involves the use of bulldozer or excavator to rid the land of trees and shrubs. Disc plough and harrowing are done in an effort to condition the soil for optimum plant growth. This method is usually employed by the very few commercial farmers within the community during my visitation.

The effects of the various farming methods above as practised by the farmers on land or soil productivity were difficult to ascertain by mere observation with the eye. These impacts on soil quality particularly soil physical properties could be measured. These measurements can then inform the choice of suitable management practices to control or limit disturbances to sustainable soil productivity over long periods. Relationships between physical properties could also inform the management of any one property so as to not adversely affect the others in the process of improving the overall soil physical condition. Notwithstanding the degradation and limited usage of poorly managed soil to the farmer and the environment as a whole, the financial obligations and duration of employing any land preparation method can also be considered in the production cost vis-à-vis the output of yield expected over the sustainable period.

Interestingly in the Afram Plains, little of these land management practices has been given due attention in literature considering the potential degradation the soil is exposed to during some of these land preparation processes.

This formed the basis for the initiation of such study into the effect of these land preparation methods on some selected soil physical properties within the farming community of the Afram Plains in Ghana.

1.2 Objectives of the Study

The main objective of this study was to determine the most appropriate initial land preparation methods in the Afram Plains and its effects on the selected soil physical properties.

The specific objectives were to:

a) To determine the effect of different initial land preparation methods on soil physical properties such as dry bulk density, porosity, hydraulic conductivity and on soil available water content.

b) To determine the relationship between hydraulic conductivity and dry bulk density and soil porosity.

c) To estimate the financial cost of the different land preparation methods employed in the Afram Plains.

CHAPTER TWO

2.0 Literature Review

2.1 Land Preparation

Land preparation is a key aspect of cropping as it promotes the rapid emergence of crop seedlings and contributes to aeration, moisturisation and nutrient cycling within a soil medium for the growth of crops (Audain K, 2012). Conventional land preparation typically involves management of crop fields through tillage and field leveling operations to make it suitable for crop establishment. This may include clearing bushes and trees so as to encourage other farm machinery operations on the land during cropping. Seedbed or land preparation is crucial for crop establishment, growth and ultimate yield (Atkinson *et al*., 2007). Preparation stages do vary according to the soil type and crops being planted. The suitability of a soil for sustaining plant growth and biological activity is a function of physical and chemical properties (Mulumba and Lal, 2008). An improper land preparation can result in soil erosion, crusting and poor drainage of the field (Amante *et al.*, 2008). The success of on-farm soil water conservation however depends upon many physical soil factors such as soil bulk density, porosity, soil surface sealing and crusting, hardpans, and hydraulic conductivity and infiltration rates as they determine the hydrological properties of soil (Strudley *et al.*, 2008). It is therefore essential to select a tillage practice that sustains the soil physical properties required for successful growth of agricultural crops (Jabro *et al*., 2009).

Judiciously used tillage can be a powerful tool in alleviating some soil-related constraints and enhancing crop production, whereas improperly used tillage can lead to degradation of soil, and pollution of water and environment (Sharma and Behera, 2008). The degree of soil disturbance depends on the type of implement used, the number of passes, type of soil, and intended crop type (FAO, 2000).

Depending on the level of cropping, simple tools as hoes and shovels to complex machines as tractors and its aggregates are applied in tilling the soil during its preparation. These implements exert stress on soil (McCarthy, 2008). Methods of clearing land and subsequent tillage practices or systems adopted must be selected to improve soil quality. However, the changes in soil properties differ among management practices (Elder and Lal, 2008).

2.2 Land Clearing

Agricultural land clearing requires the removal of land cover, including trees, bushes and shrubs from the land surface, with minimum loss of top soil as this contains the essential nutrients. Nwuba and Fashina (1987) posited that agricultural land clearing consists of the following operations: stumping or mechanical knockdown, heaping or windrowing, wood cutting, burning and removal of debris, and pioneer ploughing. A well cleared land makes mechanization of agricultural operations easy and cost effective. High frequency of machine breakdown is associated with incomplete land clearing operations, while poor yield may result from excessive tampering of the top soil (Umeghalu and Ngini, 2013).

Clearing and developing land for agricultural purposes can take more than one year. In good practice, appropriate buffer zones are preserved along all watercourses to maintain some important habitat for living organisms. Generally, land should be cleared when the ground is dry and precipitation and runoff are typically low. Methods of clearing land are however influenced by tree size and density, prevailing soil conditions and rainfall amount during the clearing season. Land clearing operation can be accomplished through the use of one or more of these methods: 1. Hand method. (2) Burning. (3) Chemical method. (4) Explosive blasting. (5) Mechanical methods.

Hand Method

This method involves use of hand tools such as matchet, hoes, axes, diggers for land clearing. However, when vegetation is thick, it is very tedious and costly. This method does not encourage mass production in agricultural production because of drudgery involved. It is also very difficult to work in the field cleared by this method because of the presence of stumps and underfoot which forms impediment to agricultural machines.

Burning Method

Burning method of land clearing is very common for a variety of reasons: it clears the land for cultivation and for travel; it provides grazing at the time of the year when the grass is at its scariest; it drives game from cover thus facilitating their capture; man appears to enjoy the sight of a good blaze especially at night. However, indications are that this method adversely affects the soil in that the earthworm and microbial populations decrease as do the organic matter and nitrogen content and general fertility.

Chemical Method

Stumps and regrowth can be eliminated or killed by the use of arboricides or herbicides. These are artificially prepared chemicals which kill unwanted forest trees. The arboricides that contain sodium arsenite are highly poisonous to alienate the growth of the trees.

Explosive Blasting Method

This method is employed to remove very big stumps to avoid excessive excavation of the soil. A wood auger is used to make a hold in the centre of the big stump and an appropriate quantity of dynamite is applied and remotely detonated to shatter the wood (Nwuba, 1979).

In cases of smaller stumps, the soil auger may be used to bore hole in the soil and apply the explosive under the stump. This again shatters and removes the stump upon detonation.

Mechanical Method

Mechanical method is employed usually when a large area of land is required because of the cost. In this method of land clearing, various mechanical equipment are used. Some of the procedures for mechanical land clearing are: surveying, knockdown of trees, windrowing, burning and removal of debris, and pioneer ploughing. Survey helps to determine the size of tractor, the type and size of matched equipment, and the clearing method to be used (Nwuba, 1984). Two main operations are involved in mechanical land clearing: knockdown and windrowing, and removal of debris. The knockdown is the process of pulling or pushing down of the trees. Various mechanical tools are employed for the process which are: bulldozer blade, the tree pusher, the clearing rake, the shearing blades, the rolling chopper, the anchor chain, and the winching cable.

2.3 Tillage Operations

Tillage includes all operations of seedbed preparation that optimize soil and environmental conditions for seed germination, seedling establishment and crop growth. Tillage can also be stated as any physical loosening of the soil in the processes of cultivation operations, either by hand or machinery. The overall goal of tillage is to increase crop production while conserving resources (soil and water) and protecting the environment (FAO, 2012) Tillage is a fundamental practice of agricultural management and it is a way of working on the soil to create suitable conditions for seedling germination, establishment and growth (FAO, 2012). Tillage practices must be such that soil is adequately conserved while maintaining high productivity of the soil medium (Ojeniyi, 2010).

Tillage is classified as either primary or secondary and in some cases tertiary when it is used in crop husbandry to control weeds and inject fertilizers, etc. The initial breakdown of soil mostly at deeper depth of 15cm or more is considered primary tillage whiles a subsequent breakdown of the clods at a much shallow depth that makes the seed bed ready for planting as secondary tillage (Parker, 2009). Various ploughing implements are employed during primary tillage whereas harrows and cultivators usually comprise secondary tillage equipment. Tillage is also sometimes categorized according to level of crop residue maintained when the conservation of soil minerals and properties is emphasized on for land and agricultural (CTIC, 2004). Tillage is then classified as conventional and conservational with its degrees of vegetation cover that is maintained during operations. Conventional tillage is somehow what is predominant in the Afram Plains with many of the local farmers having their fields ploughed and some further harrowing during cultivation. High cost of initial mechanized farming methods contributes to its avoidance according to the local farmers as most of them are low income peasant farmers.

2.3.1 Conventional Tillage

The conventional or traditional or system is based on mechanical soil manipulation of the entire field and involves disc ploughing followed by one or two harrowing operations (Memon *et. al.*, 2013). Primary plough-tillage embraces soil cultivation based on ploughing or soil inversion. This is followed by secondary cultivation using discs harrows and cultivators. These tools are often drawn by animals or tractors or by other mechanically powered devices (FAO, 2000). Ploughing removes the vegetation cover and exposes the soil to rainfall, wind and overland flow (Waugh, 2000). The mechanical soil disturbance involved increases the risk of erosion (Aina, 2011). Mechanized tillage in Afram Plains can largely be considered conventional with the disc plough as the most widely used plough during tillage. The disc plough is also employed in many cases as was being practiced by the local farmers in stumping the field after initial vegetative clearance. The use of harrows in most fields after ploughing was not universal in the Afram Plains as many farmers either abandon that due to cost or lack of secondary tillage appreciation.

2.3.2 Conservation Tillage

Conservation agriculture is aimed at soil and water management in agricultural crop production. The system maintains acceptable profits together with high and sustained production levels in a conserved environment (FAO, 2007). Conservation tillage can be defined as a crop cultivation system that allows minimum disturbance of the soil to allow crops to be sown while ensuring maintenance of crop residues on the surface (FAO, 1993). Crop residue management is defined by the *Conservation Tillage Information Center* (CTIC, 2004) as a year-round system beginning with the selection of crops that produce sufficient quantities of residue and may include the use of cover crops after low residue producing crops. The crop residue left on the surface reduces rain drop impact and reduces surface water movement, hence soil erosion. Rainfall on land that is not protected by a layer of mulch is left open to the rain. But when soils are covered with a layer of mulch, the ground is protected in a way so that the ground is not directly impacted by rainfall (Hobbs *et al.*, 2008). Most conservation tillage systems are based on one of the following reduced soil disturbance planting systems: no-till, ridge-till, mulch-till, or strip-till. Conservational tillage in its definition by remained plant cover has technically not been observed to be practiced in the Afram Plains even though there are few traditional farms which have carried out cropping without any form of tillage application other than direct seed planting. The many forms of tillage carried out in Afram Plains displayed non conformance to specific land conservation techniques but showed adherence to erosion control in the direction of plough systems.

2.4 Environmental Concerns during Land Preparations

Empirical studies indicate that severe degradation of soils' productive capacity has occurred on over 10% of the Earth's vegetated land as a result of soil erosion, excessive tillage, and overgrazing etc. (Eldar and Lal, 2008). Farming systems today have more obvious and detectable social, ecological, economic, and environmental implications than ever before because of the growing concerns about agricultural sustainability and the environment (Shrestha and Clements, 2003). Agricultural sustainability implies an increasing trend in per capita productivity to meet the present needs without jeopardizing the future potential. This demands appropriate methods of land stewardship for the development of sustainable agricultural systems. An important aspect of land stewardship is tillage, the agricultural preparation or manipulation of soil employed in crop production. Soil tillage influences agricultural sustainability through its effects on soil processes, soil properties, and crop growth (Teklu, 2011). An important effect of soil tillage on sustainability is through its impact on the environment e.g. soil degradation, water quality, emission of greenhouse gases from soil-related processes, etc., (Aina, 2011).). In the process of tillage, soil and dust emissions into the environment is unavoidable most times as depicted in figure 2. (Aina, 2011).

Figure 2: Dust emission during conventional tillage (Source: Aina, 2011)

Mechanical land preparation comprises a range of operations that are often necessary for the successful establishment or re-establishment of productive cultivation. Poorly-executed mechanical land preparation can result in adverse environmental effects and in particular, operations can result in sediment discharges to water bodies (BEPs, 2007). Other potential harmful effects include soil compaction and soil displacement. Tillage also exposes the soil to all forms of degradation and structural destruction (Buyinza, 2010). Soil tillage by use of heavy duty equipment and implements, and even farm animals often result in soil compaction, which hardens the soil and affects the infiltration characteristics of the soil (Alam *et. al.*, 2013). The continuous use of soil in tropical areas without recourse to conservation practices often constrained the soil ecosystems beyond their natural capacity, consequently leading to reduction in soil productivity and sustainability (Jongruaysup *et al.*, 2003).

However, the major environmental concern related to soil preparation is erosion (USDA, 2007). Soil erosion is a natural process that occurs when the actions of water and/or wind cause topsoil to be removed and carried elsewhere. Soil erosion can be caused by either water or wind. *Water erosion* is caused by the erosive power of raindrops falling on the soil (particularly if the soil is not covered by vegetation or residue) or by surface runoff (Norris, 2008). *Wind erosion* is particularly a problem in windy areas when the soil is not protected by residue cover.

A major environmental concern of land preparations experienced in Afram Plains can be erosion as most lands have their top soils mostly washed away after few seasons of cropping due to poor land management. This is evident in the many agriculturally unproductive lands abandoned by local farmers and more so by those who apply mechanical form of tillage within the Afram Plains.

2.5 Effects of Land Preparations on Soil Properties

Soil tillage is often needed to control weeds and ensure crop growth ahead of the germination of new flush of weeds (FAO, 2012). Tillage however exposes the soil to all forms of degradation and structural destruction (Buyinza, 2010). Soil tillage by use of heavy duty equipment and implements, hardens the soil and affects the infiltration characteristics, increase soil bulk density and penetration resistance, and reduces yield in root crops (Fasinmirin and Reichert, 2011). The continuous use of soil in tropical areas without recourse to conservation practices often constrained the soil leading to reduction in soil productivity and sustainability (Jongruaysup *et al.*, 2003).Tillage is known to have a wide range of effects on soil physical properties, (Alam *et al.*, 2013). Changes in land use and its cultivation have significant effect on soil physical properties (Yuksek *et al.*, 2009). There have been contrasts in results from tillage research due to different soils, climate and experimental designs. An experiment carried out to determine the effect of hand tractor implement on soil physical properties by Penchon *et al.*, (2007) also showed effect on the soil physical properties with the number of passes in tillage. Conservation tillage systems where a significant amount of residue cover is maintained in preparing the land aids in increasing the amount of water stored in the soil profile as surface residues reduce evaporation and increase water infiltration (CTIC, 2004).

Fasinmirin and Reichert (2011) reviewed the effect of tillage systems on soil bulk density and total porosity by conducting an investigation into effectiveness of soil conservation on optimum production of cassava in the tropics. The review indicated that the bulk density in plots under conventional tillage was not significantly different from the value of bulk density in plots under minimum tillage within the shallow soil layer however the highest was also recorded in soils under compaction due to traffic passes of heavy duty equipment. Soils under no-till were characterized by lowest bulk density within the 0–5 cm layer, but gradually increased in bulk density within the 10–20 cm soil layer, which offers the soil some structural stability. However, the difference in bulk densities between plots under no-till and compaction treatments were highly significant, with compacted plots having the highest bulk density within the 0–30 cm soil layer. Total porosity was highest in soils under conventional tillage compared with other tillage systems. Total porosity was least in plots under traffic passes (compacted plots).

Land clearing methods in the process of establishing suitable seed beds may have been overlooked in the traditional slashing and burning as in the contribution of effect on soil physical properties. Probably this method will be much more scrutinized by environmentalists rather than agronomists. A research by Pantami *et al.,* 2010, in Nigeria on the effect of burning on soil physical properties revealed that bulk density and water holding capacity were seen to be significantly affected by burning. Bulk density increased from a mean value of 1.35 gcm^{-3} to 1.53 gcm^{-3} as a result of zero-burning and intense burning respectively within the lowland areas and from 1.4135 gcm^{-3} to 1.5635 gcm^{-3} for the same treatments within the upland areas. The water holding capacity was observed to reduce from a mean value of 37.47% to 35.90% within the lowland areas while within the upland areas the reduction was from a mean value of 35.44% to 28.85% for similar treatments. In a review on the effect of soil physical properties on soil moisture, Strudley *et al.,* (2008) showed that bulk density, porosity, hydraulic conductivity, and infiltration rates were highly influenced by different tillage. Therefore, the choice of any tillage system is too critical for maintenance of the soil physical properties necessary for crop growth. However, the resulting effect of tillage on selected physical properties depends on the site-specific biophysical environment such as seasonal variability in rainfall, inherent soil fertility status, or the prevailing climatic conditions (Abbaspour-Gilandeh *et al.,* 2009).

CHAPTER THREE

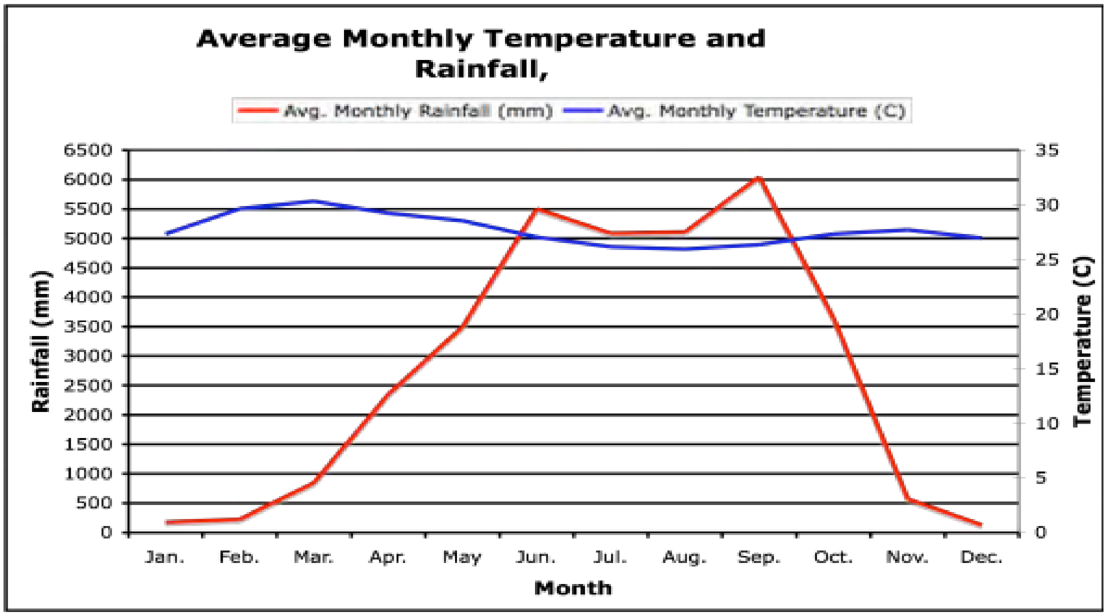
3.0 Materials and Methods

3.1 Project Site

A prior survey was carried out in August, 2012 to determine the land preparation methods employed by the local farmers and select appropriate site for the studies. Information collected during the survey included the land clearing methods, application of tillage systems, farm sizes, cost of preparing lands and cropping systems. Following the survey and determination of the soil type found within the study area, an uncultivated field was selected and demarcated to employ the identified three land preparation methods within Odumesua in the Afram Plains. The experiment was conducted applying their methods of land clearance and tillage applications carried out on the fields.

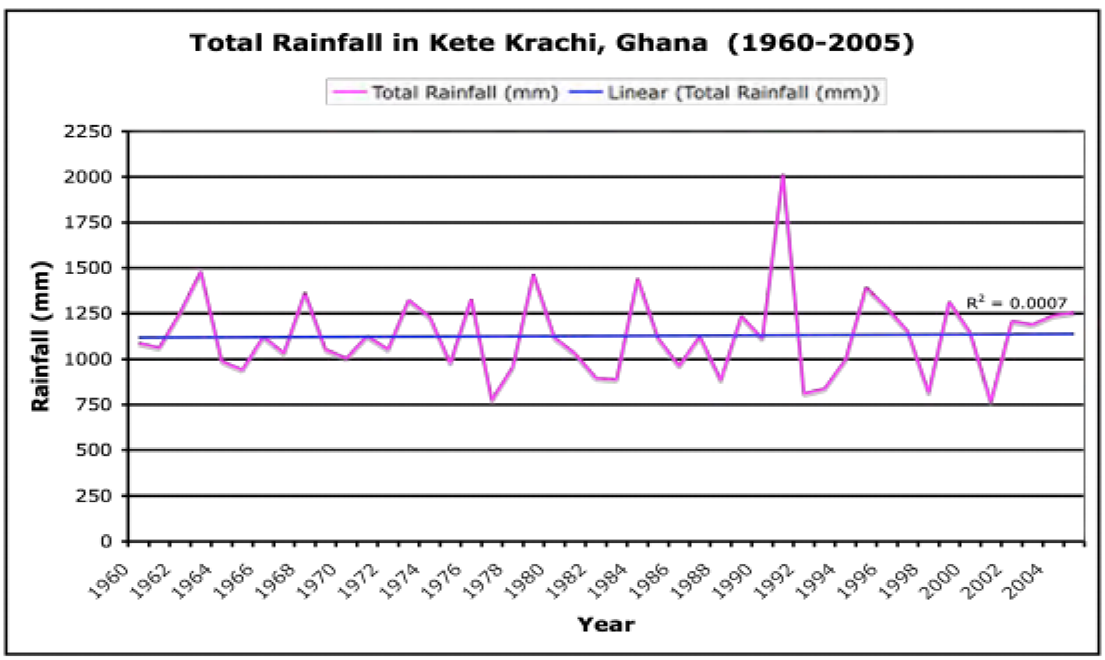
A suitable location based on soil textural analysis was selected within the ecological forest savannah transition vegetation zone of the Afram Plains Districts (6º 45‘N and 7º 13'N and longitude 1º 0'W and 0º 10'E latitudes) at Odumesua, representing one of the dominant local soil categorisation, Ejura-Kplesawgu series, within the region. It is located at an elevation of 131 metres above sea level. Major soil types in the area include luvisols (FAO, 1998) which provide adequate organic matter and clay particles for agriculture (Dietrich, 2008). High temperatures and a bi-modal rainfall regime characterize the Afram Plains climate. The region has an average temperature of 27 degrees Celsius as determined from the most complete long-term climate record at Kete Krachi, a city about 80 kilometers north of the Afram Plains. The warmest temperatures occur in the months of February and March and the coolest in August. Average rainfall is around 1100 mm (44 in.) per year in Kete Krachi from 1960-2005 (Figure 3a). Most precipitation in the Afram Plains falls from

June to September. Data from Kete Krechi suggests a slight increase in yearly precipitation from 1960-2005 (Figure 3b).



(Source: Dietrich, 2008)

Figure 3a: Average monthly rainfall and temperature in Kete Krachi-18km from Afarm Plains, Ghana from 1975-2005.



Source: Dietrich, (2008).

Figure 3b: Total yearly rainfall in Kete Krachi-18km from Afarm Plains, Ghana from 1960-2005

3.2 Field Experiment

Field experiment and soil sampling was conducted approximately 11.3 km southwest away from the main Odumesua town (N 06.90289 W 000.27335) and 3 km northeast to Tease, the district capital of the Afram Plains South District between the period of August, 2012 and April, 2013. Final samples were collected three days after heavy down pour of rain commencing the main farming season which falls between April and July of which three-quarters of annual rainfall recorded in this region is experienced.

3.3 Soil Textural Analysis

The selected field was divided into four zones and three samples were randomly collected from each zone with a 5cm-diameter core at depths of 10 cm up to a total depth of 40 cm. These samples were taken and boxed together to determine soil textural profile for the field. Textural analysis was conducted using hydrometer method.

3.4 Experimental Design

A randomized complete block design with one observation per cell was used with a two factorial of land preparation method and depth of sampling. Three initial land preparation methods were separately carried out and analysed on a selected uncultivated field. These are the Slash and Burn Clearing with No-Tillage (SBNT) method, Manual Clearing with Tillage (MCT) method and Bulldozed Clearing with Tillage (BCT) method. In the SBNT method, vegetation or weeds were cleared between trees and shrubs with hoes and cutlasses on a land area of an acre. Large trees (base area of over 0.1 m^2) were left standing but had their barks peeled off close to the base and then set on fire at the base after a week of drying to inhibit growth of the trees thereby weakening and killing it (Figures 4 and 5). In this method, no machine tillage was applied after clearing before cropping was to be carried out.

Figure 5: Field prepared with the SBNT method

Figure 4: A tree burnt from the base

The MCT method had the selected field cleared with hoes and cutlasses with large trees cut down using mattocks and chain saws which left stumps within the soil. The stumps were uprooted where possible with human labour and disc-ploughed once across the field both to remove tiny stumps and till the soil followed by disc harrowing before cropping was carried out.

With the BCT method, the chosen field was wholly cleared of its vegetation with a tractor bulldozer knocking down trees and pushing them to the boundaries. This operation was followed with disc-ploughing to till the cleared land before the introduction of disc-harrow to further pulverize and condition the soil for cropping.

3.5 Land Clearing and Tillage Operations

The demarcated fields of one acre each was cleared with cutlasses and hoes in the SBNT method whiles an electric operated chain saw and mattocks were additionally employed in the MCT method to cut down trees which were slightly difficult to be handled by a cutlass. In the BCT method, vegetative clearing was carried out with the Komatsu PC 200-Tractor bulldozer with ripper of 116 kW Gross power, operating weight of 20010 kg and fuel capacity of 400 L (Figure 6).

Figure 6: The Komatsu PC 200 Tractor de-stumping the field off trees and shrubs

In the ploughing operation, a 2.3 m width single disc plough pulled by a 53.7 kW 375 S Massey Ferguson wheeled tractor model was employed once across the fields in the MCT and BCT methods to break the soil. The Massey Ferguson tractor also powered a disc harrow (Figure 7) employed to further pulverize the soil on the bulldozed and manually cleared lands after ploughing.

Figure 7: Ploughing being carried out on field prepared with MCT method

3.6 Soil Sampling

Soil samples were collected at a depth of 10 cm, 20 cm, 30 cm, and 40 cm. The 40 cm depth was due to agronomic root zone depth for most arable crops within the area after the land preparation methods on the selected plots (Figure 8). The physical properties of the soils collected at these depths were used to determine the following physical parameters or properties: bulk density, soil porosity, hydraulic conductivity and soil moisture content.

Figure 8: Soil sampling on the field

3.6.1 Soil Dry Bulk Density

Soil samples for bulk density were randomly collected at 10 cm intervals up to a total depth of 40 cm with a 4.7cm diameter core of height 5.1cm before and after the land preparation methods on all the demarcated plots. using the core method (). Bulk Samples collected were bagged in polythene to conserve moisture and sent to the laboratory. The samples were then put in a laboratory oven for 24 hours at 105^0C to completely remove moisture and weighed to obtain dry weight of the soil and core together. Weighing of the soil samples for laboratory analyses was done using an electric balance, Model ADP 3100L. The volumes of the core samples were determined and the method of Grossman and Reinsch, (2002) was used to calculate the bulk density. Dry Bulk density was calculated as follows:

$$\rho_b = \frac{M_s}{V_t} = \frac{M_s}{V_s + V_a + V_w} \qquad \textbf{.. 1}$$

Where; ρ_b - the dry bulk density,

M_s - the mass of solid,

V_a - the volume of air,

V_w -the volume of water,

V_s - the volume of solid and

V_t.- total volume

3.6.2 Soil Porosity

Soil porosity was determined from the ratio of dry bulk density to soil particle density (McKenzie *et al.*, 2002). The particle density of most soils is usually taken to be 2.65 g/cm^3 (Hillel, 1971). Therefore total porosity was calculated as follows:

$$\mathbf{P} = \left(1 - \frac{\rho_b}{\rho_s}\right) \times 100\% \qquad \textbf{.. 2}$$

Where;

P - total porosity of the soil,

ρ_b - dry bulk density of soil and

ρ_s - particle density of the soil $\approx$2.65 g/cm^3

3.6.3 Soil Hydraulic Conductivity

Saturated soil hydraulic conductivity is a constant referring to the flow of fluid through a saturated conducting medium, derived from an empirical relationship established by Darcy in 1856 between the rates of flow of water through saturated columns of sand and the hydraulic head loss. Soil hydraulic conductivity test was carried out using the falling head permeameter measurement of permeability in steady state flows (Klute, 1965) and the hydraulic conductivity, k_{sat}, was calculated using the formula:

$$k_{sat} = \frac{\mathbf{aL} \;\; \mathbf{In}\left(\frac{\mathbf{H_1}}{\mathbf{H_2}}\right)}{\mathbf{A}\,(\mathbf{t_2}-\mathbf{t_1})} \qquad \textbf{.. 3}$$

Where;

k_{sat} - soil hydraulic conductivity, (cm/h)

a - cross-sectional area of stand pipe

L - soil sample height within the core

H_1 - height of water in standpipe before drainage

H_2 - height of water in standpipe after drainage

A - cross sectional area of soil sample core

t_2-t_1 - change in time during water drainage within standpipe

3.6.4 Soil Moisture and its Characteristic Curve

Soil moisture and availability was determined through measurement of weight change when soil in contact with a porous water saturated medium was variedly pressurized to remove water from it within a ceramic plate extractor (Bittelli and Flury, 2008) in the laboratory (Figure 9 and 10). Soil sample cores saturated at least over night were placed in tightly secured pressure plate extractors at different pressures of 0.2, 0.33, 0.5, 5 and 15 bars. At each of the pressures, soil samples were taken out at equilibrium points of pressures after few days or hours and core weights of the soil samples weighed immediately to prevent the absorption or release of moisture to the environment at the prevailing pressures instead of the determined plate pressures. Weighed soil samples were then oven dried at 105^0C for at least 24 hours and reweighed again at dry point. Gravimetric moisture content (Black, 1965) was calculated using the formula

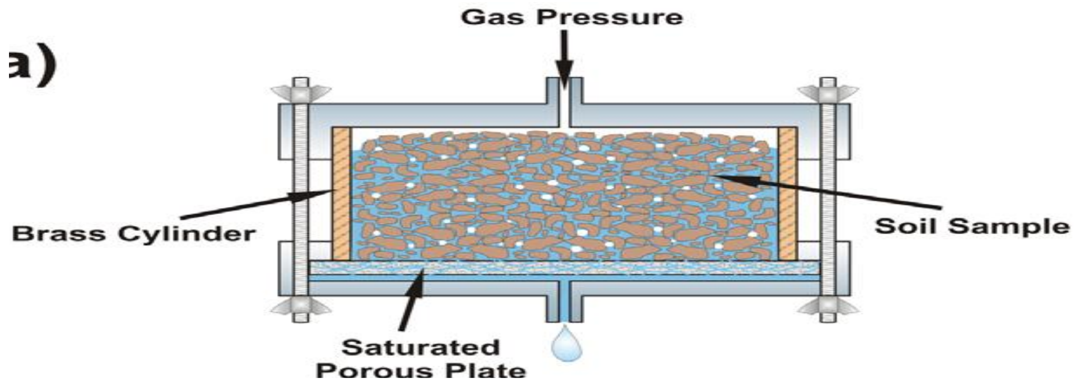
$$\theta_g = \frac{(W_{ws}+W_{ec}) - (W_{ds}+W_{ec}}{(W_{ds}+W_{ec}) - (W_{ec})} \quad \text{...} \ \mathbf{4}$$

Where; θ_g - gravimetric water content dry basis,

w_{ws} - weight of pressured wet soil sample,

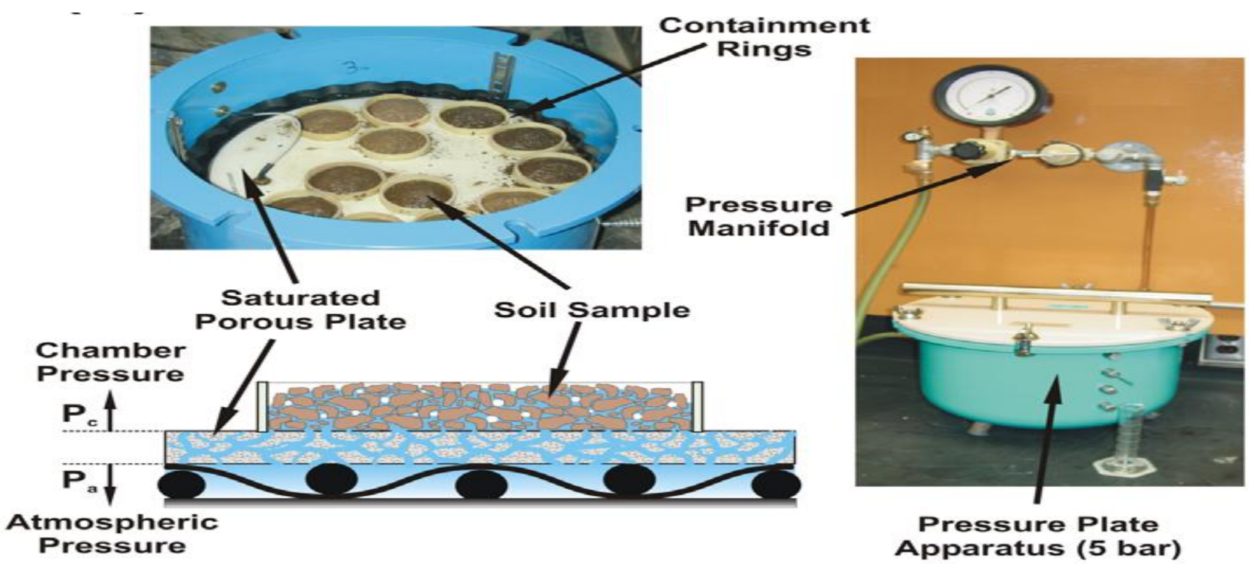
w_{ds} - weight of oven dried soil sample

w_{ec} - weight of empty can



(Source: Tuller and Or, 2003)

Figure 9: A schematic digram of the pressure plate set-up.



(Source: Tuller and Or, 2003)

Figure 10: Pressure plate apparatus in operation at Laboratory.

A relation of this weight loss with the bulk density gave the volumetric water content at determined pressure bars. Volumetric moisture content was determined through the product of the calculated dry bulk densities of the various samples with their corresponding gravimetric moisture contents. Soil moisture characteristics was demonstrated with moisture retention, characteristic or pF curves to show the relation between the suction values of the soil to its volumetric moisture content. pF expresses the force with which soil particles hold water and this force strongly depends on how much water is in the soil as a result of the change in its dynamics by machinery operations and other soil disturbance factors. From the findings in moisture retention at various bars, Available Water Content (AWC) within soils at their various depths and on the different preparation methods was derived using the change in moisture retention in all the soils samples at pressures of 0.33 and 15 bar. Available water content which is moisture difference between field capacity and permanent wilting points is usually estimated in the pressure plate set-up at 0.33 and 15 bars. Field capacity is the term used to describe maximum water content that the soil will hold following a free drainage. Permanent wilting point is taken as the lower limit of available water in dry soils beyond which water is not available to plants.

3.7 Cost Analysis of Land Preparation Methods

The considerations of input cost for the different land preparation methods was developed on the assumption of equal baseline in land acquisition and ownership for all the methods for which purpose considerations of cost was drawn out of ownership and hiring cost to farmers. Where applicable, estimates were derived from an earlier study by Mahama *et al.*, (2008), into input cost of tractor operations in Ghana using the Farmtrac 70 tractor, which is widely used in Afram Plains. In the study, the cost of any field operation could be deduced from the product of a recommended relativity index (R_x), cost of fuel per litre (C_{fuel}), time in hours taken for a unit of farming operation (t_{opr}) and a chosen profit margin of 100% increase or in this case 2 (P%). However, calculations from cost in the Afram

Plains revealed that farmers charged 200% profit margin in the hiring of harrowing and ploughing implements. This was explained by hiring agents in the Afram Plains as due to rising cost of machine maintenance in the wake of frequent breakdowns encountered on many poorly cleared lands. This further contributed to a shorter machine life span than expected.

The recommended relativity index was also estimated from calculations made factoring in fixed cost (depreciation, interests, taxes, insurance and housing) and variable cost or operating cost (repairs and maintenance, fuel, lubrication and labour). From the research (Mahama *et al.*, 2008), ploughing (Pl) and harrowing (Har) operations were approximated as 2.3 and 1.6 hours per hectare respectively. Relativity index (R_x) for ploughing and harrowing were also derived to be 12 and the current fuel price within this period (April, 2014) in Ghana for diesel per litre used was GH¢ 2.50. Where the above research findings were not applicable, for example, the case of costing for bulldozing, bush clearing activities, etc, a field interview of hiring service cost to local farmers within the community was adopted and used for the purposes of this analysis.

Bulldozing cost was estimated on the basis of hiring cost to the farmer per day, which was presented to be 1,500.00 Ghana cedis and a daily fuel requirement of 24.8 litres per hour was comparatively selected between 3-Tier 110-120kW power excavators of high operation point working 8 hours per day according to holtcat.com (2012). The literature reveals that production estimates for normal land clearing with bulldozers of heavy tractor is 3.75 hours per hectare using manual FM 5-434 (2000). Hence this value was adopted and rounded to 4.

Using the equation produced from Mahama *et. al.*, (2008) as:

The cost of any field operation will be the recommended relativity index x fuel cost of a litre x time in hours taken for a unit of operation x chosen commercial profit margin (50%, 100%, 150%, 200% etc).

The cost of ploughing and harrowing were calculated as follows with present local fuel cost:

3.7.1 Cost of ploughing per hectare (C_{Pl})

$$Cpl = Rx \times Cfuel \times topr \times P\% \quad \textbf{....................................... 5}$$

$$= 12 \times GH¢\ 2.50 \times 2.3 \times 2$$

$$= \textbf{GH¢ 138.00}$$

Where; C_{pl} = cost of ploughing per hectare

R_x = Relativity Index

C_{fuel} = cost of fuel per litre

t_{opr} = time in hours taken for a unit of farming operation

P% = percentage profit margin

3.7.2 Cost of harrowing per hectare (C_{Har})

$$\mathbf{C_{Har} = R_x \times C_{fuel} \times t_{opr} \times P\%} \quad \textbf{....................................... 6}$$

$$= 12 \times GH¢\ 2.50 \times 1.6 \times 2$$

$$= \textbf{GH¢ 96.00}$$

Where; C_{Har} = cost of ploughing per hectare

R_x = Relativity Index

C_{fuel} = cost of fuel per litre

t_{opr} = time in hours taken for a unit of farming operation

P% = percentage profit margin

3.7.3 Cost of bulldozing per hectare

Hiring cost of GH¢ 1,500.00 per day (8 hours of work) was charged for excavators or bulldozers and with an estimated bulldozing hours per hectare as 4, hiring cost for per hectare was derived as according to FM 5-434 (2000);

If 8 hours of hiring ≈ GH¢ 1,500.00

Then, 4 hours of hiring $\approx \frac{4}{8} \times$ Gh¢ 1500.00

≈ Gh¢ 750.00

Fuel consumption/hectare ($C_{fuel/ha}$) ≈ litres consumed/ hour × Operational hours × cost of fuel per litre

$$\mathbf{C_{fuel/ha} = L/h \times t_{opr} \times C_{fuel}} \qquad \textbf{7}$$

= 24.8 × 4 × GH¢ 2.50

= GH¢ 248.00

Cost of bulldozing per hectare ($C_{Bulldozing}$) = GH¢ 750.00 + GH¢ 248.00

= GH¢ 998.00

10% additional cost is factored into the bulldozing cost to cater for miscellaneous expenses which yields GH¢ 99.80

Total Cost of bulldozing per hectare ($C_{Bulldozing}$) = 998.00 + 99.80 = **GH¢ 1097.80**

Where; $C_{Bulldozing}$ = cost of bulldozing

$C_{fuel/ha}$ = cost of fuel per hectare

L/h = litres consumed per hour

t_{opr} = operational hours

C_{fuel} = cost of fuel per litre

3.7.4 Manual Clearing Cost

From field interview and feedback gathered from the local farmers, labour hired to clear bush and shrubs using simple tools were estimated at **GH¢ 200.00/hectare**.

Manual clearing with chain saw operations included was estimated at

GH¢ 325.00/hectare.

Preparation of mounds accompanies bush clearing in the manual method where mechanical tillage activities will not be carried out due to the presence of large trees and stumps paving the way for the cultivation of root crops, which is the norm for the traditional farmers in the Afram plains in during the first two years of land clearing. This was also estimated at **GH¢200.00/hectare**.

3.8 Data Analysis

The data collected was analyzed using SPSS software (version 14.0). Soil properties were analysed according to land preparation methods and depth of soil sampling. Statistical differences were tested using two-way Analysis of Variance (ANOVA) following the general linear model (GLM) procedure within SPSS. Where tests show statistically significant differences, Means were compared using Least Significant Difference (LSD). A regression analysis was also conducted between hydraulic conductivity and bulk density as well as soil porosity to establish the correlation that existed between them.

CHAPTER FOUR

4.0 Results and Discussion

Results for measured and calculated means of collected soil samples on dry bulk density, porosity, hydraulic conductivity and available water contents are presented in this chapter. A financial cost implications or analysis is further on carried out and presented also in this section to appreciate the cost involved in the employment of each land preparation method. An analysis of variance was used (at $p \leq 0.05$ significance level) to measure variations in means of the measured soil parameters at the different depths of sampling. Results obtained is further compared to other findings and discussed to ascertain the validity and importance of the findings in this study.

4.1 Textural profile and soil type determination of the Field

This experiment was conducted to determine the changes in soil physical properties as a result of agricultural land preparation through green cover removal and/or management and its attendant soil pulverization practices and measure its effect if present. This is displayed by alterations either in the improvement or deterioration of such indicative soil quality factors depending on method and intensity of the land preparation operations. The chosen field was randomly sampled to ascertain its textural profile so that a basis for soil property changes could be explained and this showed a sandy clay loam soil type with an average of 60% sand and less than 30% clay composition as seen in Table 1.

Table 1: Soil Texture of the Selected Field

Soil Zone	Sand %	Silt %	Clay %	Soil Type Classification
A	63.37	10.13	28.49	Sandy Clay Loam
B	62.67	10.10	25.89	Sandy Clay Loam
C	62.76	10.18	28.65	Sandy Clay Loam
D	67.71	7.58	25.91	Sandy Clay Loam
Average	**64.13**	**9.50**	**27.24**	**Sandy Clay Loam**

Sandy clay loam soils are considered fine to medium textured soils with more clay size minerals. They may have high porosity and show small discontinuous pores making them favourable for production due to relatively high available water retention and nutrient movement.

4.2 Dry Bulk Density

Soil dry bulk density which gives an indication of how compact the soil is, was measured to ascertain the level of change assumed in relation to the uncultivated land. Dry bulk density of the soil was statistically shown to be affected by the method of pulverization and again the depth within which it was sampled.

Total mean values for soil dry bulk density was comparatively higher in the UNCULTIVATED and SBNT methods at 1.50 g/cm^3 and 1.51 g/cm^3 to the MCT and BCT methods at 1.45 g/cm^3 and 1.26 g/cm^3 respectively from Table 2.

Table 2: Dry Bulk Density (g/cm^3) of land preparation methods at different soil depths

Depths	Land preparation method				Total	
cm	UNCULTIVATED	SBNT	MCT	BCT	mean	Stdev
0-10	1.43	1.31	1.30	1.03	**1.27**	(±0.17)
10-20	1.45	1.56	1.37	1.16	**1.39**	(±0.17)
20-30	1.55	1.57	1.52	1.39	**1.51**	(±0.08)
30-40	1.58	1.59	1.60	1.47	**1.56**	(±0.06)
Total mean	**1.50**	**1.51**	**1.45**	**1.26**		
Stdev	(±0.07)	(±0.13)	(±0.14)	(±0.20)		

The lowest dry bulk density value was recorded after tillage at BCT at 0-10 cm depth at 1.03 g/cm^3 and the highest at MCT within the depth of 30-40 cm. Dry bulk density total mean values also increased statistically with increasing depth of sampling from 1.27 g/cm^3 at 0-10 cm to 1.56 g/cm^3 at 30-40 cm.

There was statistically significant effect of land preparation methods and depth of sampling on mean dry bulk density values at $p \leq 0.05$ significance level as displayed in Table 3.

Table 3: ANOVA for Tests of Between-Subjects effects for dry bulk density

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	
Corrected Model	0.364(a)	6	0.061	12.532	0.001	**S**
Intercept	32.718	1	32.718	6761.552	0.000	**S**
L. P. Method	0.159	3	0.053	10.918	0.002	**S**
Depth	0.205	3	0.068	14.146	0.001	**S**
Error	0.044	9	0.005			
Total	33.126	16				
Corrected Total	0.407	15				

a R Squared = .893 (Adjusted R Squared = .822) df= degree of freedom; F= calculated F-test value; Sig. = Significance level at α=0.05; L. P. Method = Land preparation method S= significant at $P \leq 0.005$

Least significant difference (LSD) test further showed that there was a significant difference ($p \leq 0.05$) between mean values of BCT and the other two methods employed but there was no significant difference amongst SBNT, MCT and the UNCULTIVATED as detailed in the Appendix III. There was also a significant difference between mean dry bulk density values along the various depth of sampling except between the 20-30 cm and 30-40 cm depths.

Generally, bulk density increased with increasing soil depth but this increase was much greater within the 0-30 cm of the soil than was for the 30-40 cm depth, which could be attributed to the depth of operation by the tillage implements falling within 20 cm root zone depth of most vegetable and staple crops. The trend in data also revealed dry bulk density was 0.05 g/cm^3 and 0.24 g/cm^3 less in MCT and BCT, respectively than was recorded for the UNCULTIVATED and SBNT at almost equal means of 1.50 g/cm^3. This agrees with results in other experiments where no-till land were compared to both conventional and reduced tillage which showed greater bulk density in no-till lands especially in the first 10 cm depth of the soil (Fabrizzi *et al.*, 2005, McVay *et al.*, 2006; Khan *et al.*, 2001). This result also however contradicted results obtained by Osunbitan *et al.*, (2005) on tillage effects on dry bulk density in Southwestern Nigeria. SBNT showed least disparity in relation to the UNCULTIVATED. This can broadly be due to near absent pulverization achieved in SBNT as against higher clods or soil aggregates broken down with mechanical equipment in tillage. BCT, which employed the use of heavy field machinery will lead to a much higher compaction expectation and display a relatively higher mean bulk density as reported by Agbede, (2006), but this effect was significantly reduced partly by the deep level of pulverization achieved in its bulldozed tree stumping and also its accompanied tillage operations (Karuma *et al.,* 2014). Generally, mean bulk densities below 1.0 g/cm^3 are considered low but above this, tillage is required whiles above 2.0 g/cm3, it is said to be also too high for cropping. However, all bulk densities within this study scope of land preparation methods fell below 1.6 g/cm^3 above which it can restrict root growth and result in low levels of water movement into and within soil (Mckenzie *et al.*, 2002).

4.3 Porosity

Movement of water in soils is demonstrated by the amount of pore space within it (Tan, 2005). Pore space content of soil is regarded as means of soil pore characterization. This was measured after the determination of bulk density which is inversely proportional to porosity (Mckenzie *et al.*, 2002). Calculation of soil porosity was made from a relation of dry bulk density to the particle density of soil. Estimated total mean soil porosity values amongst the land preparation methods was least at 43.14% for SBNT and the highest was recorded for BCT at 52.36% (Table 4).

Table 4: Soil Porosity (%) of land preparation methods at different soil depths

Depths	**Land preparation method**				**Total**	
Cm	**UNCULTIVATED**	**SBNT**	**MCT**	**BCT**	**mean**	**Stdev**
0-10	45.93	50.66	50.94	61.19	**52.18**	(±6.43)
10-20	45.33	41.15	48.21	56.19	**47.72**	(±6.35)
20-30	41.64	40.77	42.61	47.58	**43.15**	(±3.05)
30-40	40.44	39.98	39.45	44.47	**41.09**	(±2.29)
Total mean	**43.34**	**43.14**	**45.30**	**52.36**		
Stdev	(±2.71)	(±5.04)	(±5.22)	(±7.70)		

Along the depth of sampling, total mean soil porosity declined as soil depth increased from 52.18% at 0-10 cm soil depth to 41.09% at 30-40 cm soil depth. The highest mean porosity of 61.19% was recorded at BCT within the soil depth of 10 cm whiles the lowest occurred under MCT within depth 30-40 cm.

A multiple comparison effect with Least Significant Difference (LSD) test detailed in Appendix IV for mean soil porosity values among land preparation methods showed that statistically significant differences existed between BCT values and the other methods. However there was the land preparation methods showed significant effect in determination of this soil property at p≤ 0.05 significance level in Table 5. There was no significant difference between the UNCULTIVATED, SBNT and MCT methods at p≤ 0.05 significance level. Within the depth of sampling, a further LSD test also indicated that there were significant differences in total mean values for amongst all the depths of sampling but not between the depths of 20-30 cm and 30-40 cm. Generally, mean soil porosity values showed a decline with increasing soil depth for all the land preparation methods.

Table 5: ANOVA for Tests of Between-Subjects effects for soil porosity

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	
Corrected Model	518.430(a)	6	86.405	12.179	0.001	**S**
Intercept	33905.698	1	33905.698	4779.057	0.000	**S**
L. P. Method	224.726	3	74.909	10.559	0.003	**S**
Depth	293.704	3	97.901	13.799	0.001	**S**
Error	63.852	9	7.095			
Total	34487.980	16				
Corrected Total	582.282	15				

a R Squared = .890 (Adjusted R Squared = .817) df= degree of freedom; F= calculated F-test value; Sig. = Significance level at α=0.05; L. P. Method = Land preparation method S=significance at P≤0.005

Results indicated only BCT with an average porosity above 50%, which is ideally expected for fertile agricultural soils (Aikins *et al.*, 2005). This was as a result of the corresponding effect of a relatively lower bulk density generated through clods breaking from the bulldozing and subsequent tillage operations carried out agreeing with results of Karuma *et al.*, (2014) on increasing porosity under conventional tillage. Land preparation method has been shown to be a significant factor in porosity determination as the manipulation of soil structure leads to aggregate separation and loosening. This was confirmed by Teklu (2011) in his findings on the effect of tillage on physical qualities of soil in Ethiopia as significant. The mean porosity for UNCULTIVATED was accordingly low as deduced from its dry bulk density. The depth of sampling was shown to be a significant factor in the determination of soil porosity. The first 10 cm soil depth showed a more porous soil due to higher pulverization experienced within the operational depths of the discs and harrows employed during tillage. This agreed with results recorded by Aikins and Afuakwa (2012) in the study of the effect of different tillage practices on soil physical properties in Ghana. This higher porosity again showed in SBNT as the manual tilling of the soil achieved highest within this range. Low total porosity in the UNCULTIVATED agrees with researches that maintained lower porosities in no-till fields to tilled ones partly due to high organic matter presence and higher compaction within the untilled top soils (Elder and Lal, 2008, Aikins and Afuakwa, 2012).

General trend in the comparison of methods depicted decreasing porosity with increasing depth as soil structure remains more stable and compact beyond the reach of deep tillage. Again, data gathered from the study corresponded to most savannah soils with porosity ranging mostly between 32% and 44% (Aikins *et al*., 2005).

4.4 Hydraulic Conductivity

Porosity influences soil hydraulic conductivity, which indicates how simply water can move through the pore spaces in the soil. Pore sizes and their cohesion determine whether permeability within the soil will be high or low. The saturated hydraulic conductivity is an indicator of the soil's ability to lead and transmit the water needed for plants to the root zone, as well as drain excess water out of the root zone *(*Erickson *et al.*, 2013*)*.This study determined the rate of water flow within the soil treated with the different land preparation methods and also measured changes that arose due to sampling at different soil depths.

Soil hydraulic conductivity values were higher in UNCULTIVATED and SBNT at 1.97 cm/h and 1.98 cm/h than in MCT and BCT at 2.16 cm/h and 2.45 cm/h respectively as shown in Table 6.

Table 6: Hydraulic Conductivity of land preparation methods at soil depths

Depths	**Land preparation method**				**Total**	
cm	**UNCULTIVATED**	**SBNT**	**MCT**	**BCT**	**mean**	**Stdev**
0-10	1.93	2.04	2.19	2.71	**2.22**	(±0.35)
10-20	1.89	1.95	2.22	2.84	**2.22**	(±0.43)
20-30	2.07	1.93	2.21	2.13	**2.09**	(±0.12)
30-40	1.97	1.99	2.01	2.11	**2.02**	(±0.06)
Total mean	**1.97**	**1.98**	**2.16**	**2.45**		
Stdev	(±0.08)	(±0.05)	(±0.10)	(±0.38)		

Results along the depth of sampling also showed that total mean hydraulic conductivity values was the same at the initial soil depth profiles of 0-10 cm and 10-20 cm at 2.22 cm/h before marginally declining to 2.09 cm/h and 2.02 cm/h at depth 20-30 cm and 30-40 cm respectively. The highest mean hydraulic conductivity was recorded in BCT within the depth of 10-20 cm at 2.54 cm/h and the least mean value was determined as 1.85 cm/h in the UNCULTIVATED at depth 30-40 cm.

Statistically, the soil depth of sampling did not have any significant effect on hydraulic conductivity mean values at $p \leq 0.05$ significance level. However, land preparation method was significant in the determination of the mean values shown in Table 7, in agreement with Teklu (2011) but contrary to findings of Karuma *et al.*, (2014). Among the land preparation methods, mean difference of hydraulic conductivity values was established to be significant between BCT and UNCULTIVATED and then also between BCT and SBNT as detailed in the Appendix III. To this, Green *et al.*, (2003) also reported that the effects of tillage on the soil hydraulic properties under different tillage treatments are not always consistent across locations, soils and experiment designs.

Table 7: ANOVA for Tests of Between-Subjects effects for soil hydraulic conductivity

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	
Corrected Model	0.730(a)	6	0.122	2.962	0.070	**NS**
Intercept	73.060	1	73.060	1778.782	0.000	**S**
L. P. Method	0.607	3	0.202	4.930	0.027	**S**
Depth	0.122	3	0.041	0.994	0.439	**NS**
Error	0.370	9	0.041			
Total	74.159	16				
Corrected Total	1.100	15				

a R Squared = .664 (Adjusted R Squared = .440) df= degree of freedom; F= calculated F-test value; Sig. = Significance level at α=0.05; L. P. Method = Land preparation method S=significant, NS= Not significant

Saturated hydraulic conductivity mean values were shown to be insignificant along the depth of sampling but significant between the land preparation methods giving credence to the fact that this soil property depended rather more on pore size, pore distribution and its connectivity altered by tillage practices as this was the case also by Jabro *et al.*, (2010), who researched into tillage effect on bulk densities and hydraulic properties in the United States. UNCULTIVATED and SBNT methods showed a relatively similar mean hydraulic conductivity at 1.97 cm/h whiles significantly differing from the heavily pulverized BCT method at 24% agreeing more with results of Kamenickova *et al.*, (2012). Results also conformed to outcomes, which showed that saturated hydraulic conductivity increases as the bulk density decreases and soil total porosity increases, indicating that soil compaction influences hydraulic conductivity measurements at the 10–30 cm depth (Jabro *et al.*, 2010; Jabro *et al.*, 2009). From the results, UNCULTIVATED and SBNT methods suggests a slow conductivity class according to FAO standards within mean value ranges of 0.8-2.0 cm/h whiles MCT and BCT methods are considered as moderate being within the 2.0-6.0 cm/h range.

4.5 Moisture Characteristics and Available Water Content

Volumetric moisture content was recorded for the various pre-set pressures at the defined soil sampling depth for all the land preparation methods (Table 8), and moisture characteristic curve (Figure 11) were plotted showing the retention of water under these operations.

Table 8: Volumetric moisture content on land preparation methods at different depths

Land Preparation Method	Depth of Soil (cm)	Volumetric Moisture Content (%) at Different Pressures				
		0.2 bar (0.02 pF)	0.33 bar (1.5 pF)	0.5 bar (1.6 pF)	5.0 bar (2.6 pF)	15.0 bar (3.17 pF)
UNCULTIVATED	0-10	18.58	13.47	11.05	6.95	4.93
	10-20	17.88	13.71	11.68	9.42	8.21
	20-30	17.25	13.64	11.58	8.85	5.96
	30-40	20.09	15.32	13.12	10.55	7.08
SBNT	0-10	20.07	15.57	13.36	11.39	6.79
	10-20	22.87	18.09	14.80	15.21	9.13
	20-30	22.36	16.51	14.61	9.97	8.35
	30-40	22.14	16.93	14.91	9.96	8.66
MCT	0-10	20.77	13.73	10.90	7.40	5.45
	10-20	19.32	13.43	10.73	6.73	5.52
	20-30	18.85	14.80	12.05	10.17	6.91
	30-40	24.08	17.94	15.31	10.68	8.75
BCT	0-10	18.85	14.90	12.48	11.13	7.44
	10-20	17.93	13.23	13.39	8.74	6.71
	20-30	19.67	14.16	11.02	7.33	6.44
	30-40	20.18	14.26	20.41	8.05	6.75

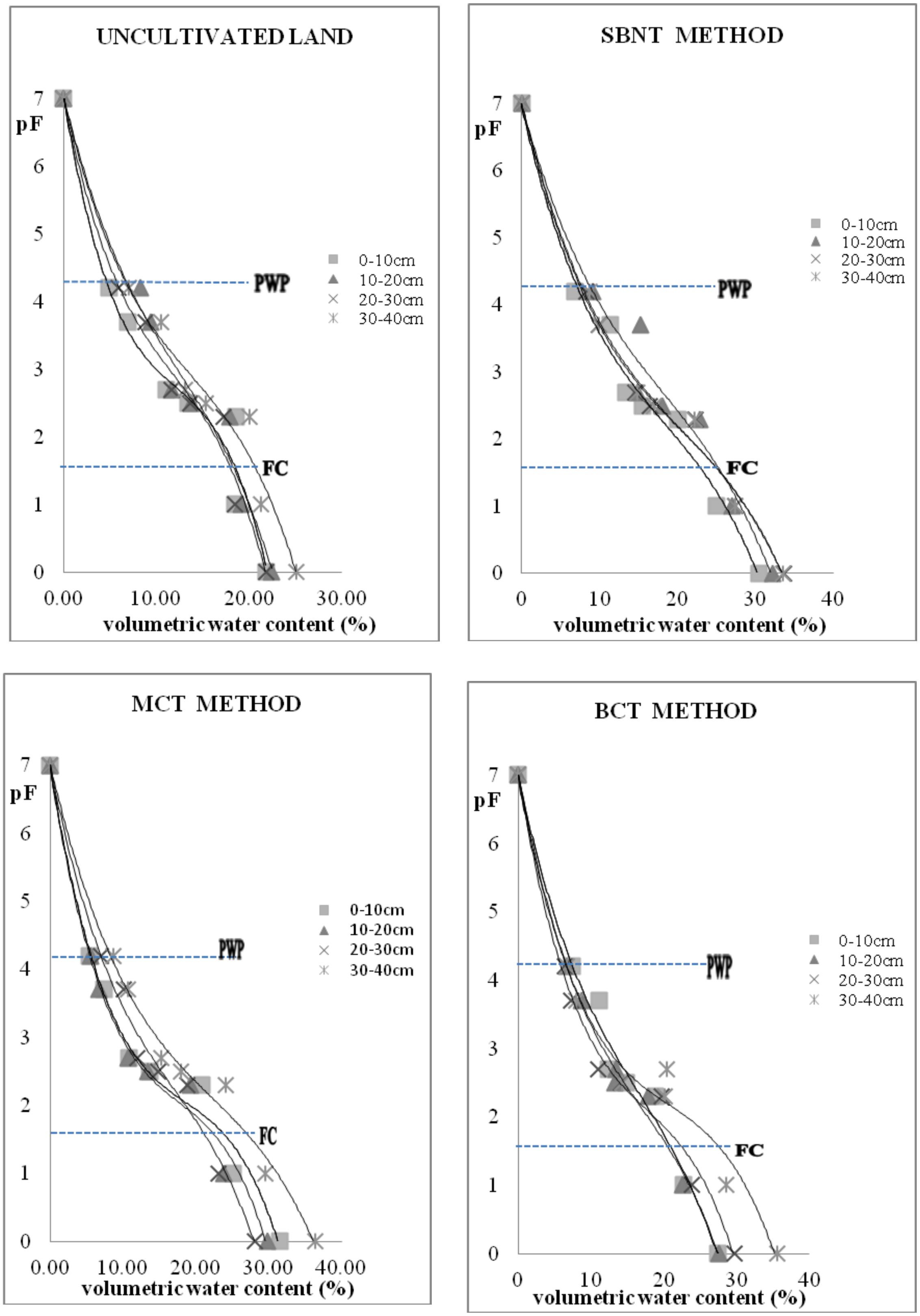


Figure 11: Moisture Retention Curves depicted for different land preparation methods at the various depths of sampling.

The difference between moisture contents at pressures of 0.33 bar and 15 bar were calculated to derive available water content accordingly for the land preparation methods at their varying soil depths. Total mean values were comparatively lower in UNCULTIVATED and BCT at 7.49% and 7.30% than SBNT and MCT at 8.54% and 8.32% respectively (Table 9). Along the depth of sampling, available water content was averagely 8.26% within the 0-10 cm depth but decreased to 7.22% and 7.86% at the depths 10-20 cm and 20-30 cm respectively before rising again to 8.30% at the depth of 30-40 cm.

Table 9: Available Water Content of land preparation methods at different soil depths

Soil Physical Property	Land Preparation Method	Depth of Soil 0-10 cm	10-20 cm	20-30 cm	30-40 cm	Total Mean
	UNCULTIVATED	8.54	5.50	7.69	8.24	**7.50**
AVAILABLE	SBNT	8.78	8.96	8.16	8.27	**8.54**
WATER	MCT	8.28	7.91	7.88	9.19	**8.32**
CONTENT	BCT	7.45	6.52	7.71	7.51	**7.30**
(m^3/m^3) %						
	Total Mean	**8.26**	**7.22**	**7.86**	**8.30**	**7.91**

Land preparation methods and depth of sampling did not show statistically significant treatment effect in the determination of available water content as displayed in Table 10. However, a multiple comparison effect showed significant difference in mean available water contents among land preparation methods was only between BCT and SBNT as detailed in Appendix II.

Table 10: ANOVA for Tests of Between-Subjects effects for available water content

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.468(a)	6	1.245	2.211	0.137
Intercept	1001.564	1	1001.564	1779.432	0.000
L. P. Method	4.454	3	1.485	2.638	0.113
Depth	3.014	3	1.005	1.785	0.220
Error	5.066	9	0.563		
Total	1014.098	16			
Corrected Total	12.534	15			

a R Squared = .596 (Adjusted R Squared = .326) df= degree of freedom; F= calculated F-test value; Sig. = Significance at α=0.05; L. P. Method = Land preparation method

Soil water characteristics is an important hydraulic property related to size and connection of pore spaces; hence strongly and directly affected by soil texture and structure and by other constituents including organic matter (Tuller and Or, 2003). This could therefore explain the statistical insignificance of either the land preparation methods or depth of sampling to the determination of available water content within the soils as its texture ultimately remains more the same through the profile affirmed by the textural analysis earlier conducted. Yet, there were little variations in the available water content which is stored between the field capacity and wilting points pointing to recorded effect exhibited by the different land preparation methods. This result however confirms studies which maintain that water retention is affected by tillage, (Abu-Hamdeh, 2004). Least available water content was recorded at BCT indicating that heavy pulverization of the soil even though may lead to a porous soil thereby increasing water flow but could not guarantee higher water retention due to weakened adhesion between soil particles contrasting findings by Abu-Hamdeh (2004), where increased soil porosity increased soil available water.

4.6 Effects of Hydraulic Conductivity and Dry Bulk Density on Soil Porosity

A regression analysis was undertaken to relate the combined data obtained from dry bulk density as well as soil porosity to hydraulic conductivity. Figures 12 and 13 illustrate the relationship between dry bulk density and hydraulic conductivity and soil porosity and hydraulic conductivity, respectively showing a good correlation amongst them with adjusted R^2 at 0.675 and 0.673 respectively with detailed analysis data in Appendix V and VI.

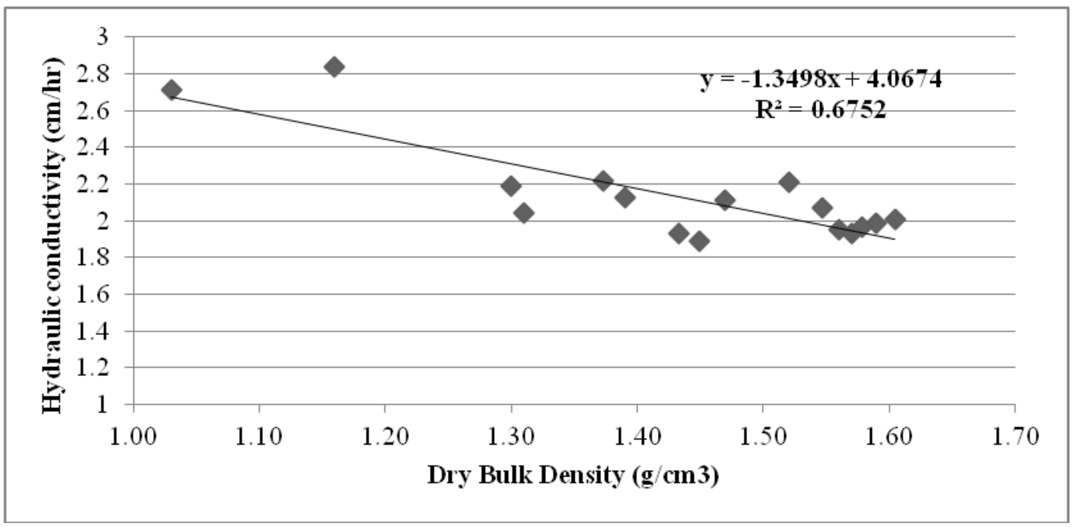


Figure 12: Dry Bulk Density versus Hydraulic Conductivity

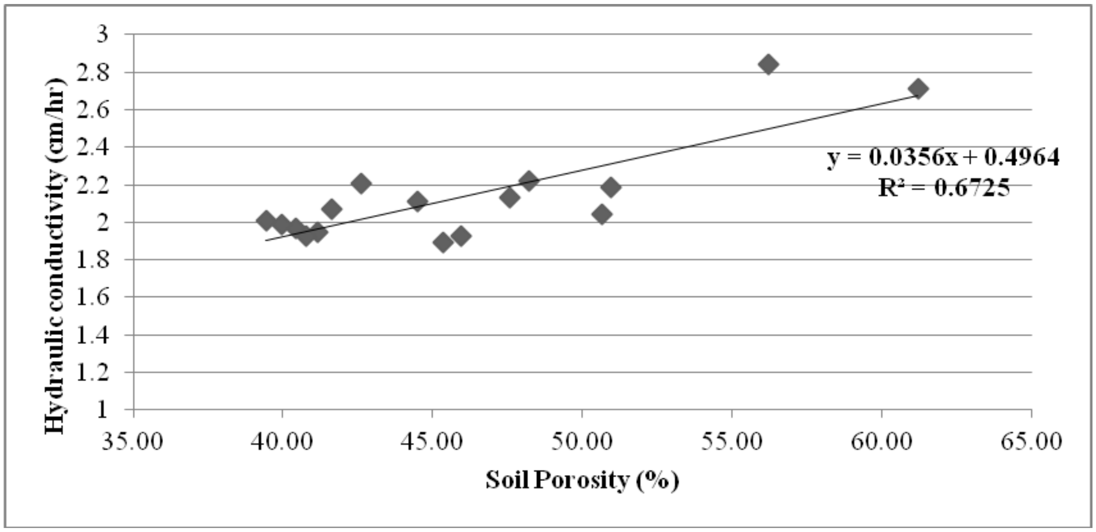


Figure 13: Soil Porosity versus Hydraulic Conductivity

The regression analysis of hydraulic conductivity and bulk density and also with porosity had shown a strong correlation. A negative relationship existed between hydraulic conductivity and bulk density but a positive relationship existed between hydraulic conductivity and soil porosity. This confirms earlier researches of inverse relationship between bulk density and hydraulic conductivity, indicating that compact soils with higher bulk densities have lower flow of water within the soil per unit time (Jabro *et al.*, 2010; Jabro *et al.*, 2009). As soils become more compact, water movement becomes difficult. A higher porosity depicts a more porous soil which can be achieved by the tillage operations carried out earlier. In this situation water movement is not much restricted enabling the cycling of nutrients within the soil. As porosity increases hydraulic conductivity also increases accordingly.

4.7 Cost Analysis of Land Preparation Methods

In this study, soil quality factors were the means of categorizing the suitability of a land preparation method which was employed during farming. Such soil property measurements are paramount for the sustainability of agricultural lands since poor soil management and manipulation many times are borne in bad tillage practices or seed bed preparations. In addition to the soil management factor is the element of cost which informs the choice of these soil management practiced by the local farmer.

A comparative cost analysis was made with an estimation of cost of operations based on methodology from literature guides and assumptions of land preparation activities and machine hiring fees held for the local farming district of the Afram Plains. The Table 11 presents an estimated cost of the land preparation methods practiced and identified within the district.

Table 11: Estimated Cost of different Land preparations in the Afram Plains

Land Preparation Activitites	SBNT GH¢	MCT GH¢	BCT GH¢
Bush and Tree clearing	200.00	325.00	1097.80
Ploughing Operation	-	138.00	138.00
Harrowing Operation	-	96.00	96.00
Seedbed (mounds) Preparation	200.00	-	-
TOTAL	400.00	559.00	1331.80

The comparative cost analysis based on derived estimations and the earlier assumptions of local land preparation charges showed that SBNT method gave the least cost for preparing the land. The MCT method costs an extra 40% more in comparison to SBNT to prepare the same land. A threefold measure and more in cost is expected if one chooses to prepare land by the BCT method in comparison to the SBNT. Comparing the BCT method with MCT method will require more than double investment (2.38 times). The estimates made in this analysis may change with changing cost components and inflationary changes associated with the economics of any non-stagnant society. However, a ratio generated in this analysis from the total cost of employing the categorized land preparation methods in the Afram Plains can be a guide to estimating land preparation costs, particularly for the district for some years to come. A cost ratio derived from relating SBNT to MCT and BCT can be put from their cost figures of 400.00: 559.00:1331.80 as **1:1.4:3.3.** It must be noted however that the standard profit margin of 100% which was used in the calculations on machinery input costing according to mechanisation requirements falls short of the profit margin of 200% charged by local farmers in the Afram Plains. Local farmers attributed this non conformity to rising cost of machine maintenance in the wake of frequent breakdowns encountered on many poorly cleared lands and a subsequent shorter machine life span than expected.

In the studies, observation of the number of hours needed to achieve the objective of each land preparation method may add to the effort of cost in timeliness especially in mechanization. Whereas the BCT method took about 8 hours to prepare a hectare of field even though it was not continuous, the SBNT and MCT did take an average period of 10 days in preparing the same hectare of field for cultivation.

CHAPTER FIVE

5.0 Conclusions and Recommendations

5.1 Conclusions

The study has shown that different land preparation methods significantly caused changes in soil physical properties.

Results from this study on the effect of the land preparation methods on the selected soil physical properties proved that the BCT method of land preparation is the most appropriate choice in preparing and conditioning soil for cultivation in the Afram Plains. This was established based on values recorded for dry bulk density and soil porosity, which gave results expected for fertile agricultural soils under soil quality indicators. The hydraulic conductivity under the BCT method was also found to be moderate. Water retention proved influenced by the soil texture rather than the BCT method. However, the cost implication of applying this method whether for the initial or over long term will have to be maintained with a corresponding greater yield.

a.) Dry bulk density and porosity were found to be significantly ($p<0.02$) affected by different land preparation methods and the depth from which these soil samples were taken. This emphasized the effect of the depth of operation of most tillage implements within the top soil profile. Dry bulk density reduced by 3-16% based on land preparation methods employed showing the effects of no-tillage and conventional tillage systems. Hydraulic properties of soils were also found to be significantly ($p<0.027$) affected by the methods of land preparation carried out. Hence there is the need for appropriate land preparation systems to boost nutrient and water recycling in soils for good crop production. The hydraulic conductivities of the soil however showed that the depth of soil sampling did not have any significant ($p<0.439$) effect on the hydraulic property of soils. This study showed that the methods of preparing lands either manually or with heavy machinery did not significantly ($p<0.113$) affect water retention and availability in soils. The soil texture and its organic matter content are the most influential factors to water retention and availability in soils.

b.) The effect of soil bulk density and soil porosity reflected strongly on the hydraulic properties of soils. Whereas an increase in porosity increases hydraulic conductivity, an increase in bulk density reduces the hydraulic conductivity of soils. This result underlines the essence of well pulverized soils which is achieved in higher mechanized systems for good soil conditioning.

c.) A comparative cost analysis of the different land preparation methods also revealed that BCT is three times (300%) more expensive than manual labour using simple hand tools in land preparation.

5.2 Recommendations

It is recommended that soil conditions are determined to inform the choice and effect of land preparation methods before cultivation so as to enhance and not degrade the expected fertile soil conditions.

Due to soil moisture as a key factor to crop growth and sustenance for most arable crops, it is recommended that selection of fields for agricultural production should consider the soil texture of the field as a major contributory factor to water availability to plants before the effect of the intended land preparation method.

Cone penetration resistance as a physical soil parameter helps the understanding of the impact of compaction and cohesion within soils especially in tillage and will therefore add to the appreciation of the findings made in this study if it is also investigated.

In the future, determination of the sustained effect of the various methods of land preparations on the soil for longer periods will establish the acceptability or development of these methods for sustainable crop growth.

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APPENDICES

SPSS data output of ANOVA using General Linear Model in version 14.0

Appendix I:Univariate Analysis of Variance (Hydraulic conductivity)

```
[DataSet1] C:\Users\DUKE\Desktop\NEWEST\DATA SET 1.sav
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Between-Subjects Factors

		Value Label	N
Land Prep. Method	1	UNCULTVTD	4
	2	SBNT	4
	3	MCT	4
	4	BCT	4
Soil Depth	10	0-10cm	4
	20	10-20cm	4
	30	20-30cm	4
	40	30-40cm	4

Descriptive Statistics

Dependent Variable: hydraulic conductivity

Land Prep. Method	Soil Depth	Mean	Std. Deviation	N
UNCULTVTD	0-10cm	1.9300	.	1
	10-20cm	1.8900	.	1
	20-30cm	2.0700	.	1
	30-40cm	1.9700	.	1
	Total	1.9650	.07724	4
SBNT	0-10cm	2.0400	.	1
	10-20cm	1.9500	.	1
	20-30cm	1.9300	.	1
	30-40cm	1.9900	.	1
	Total	1.9775	.04856	4
MCT	0-10cm	2.1900	.	1
	10-20cm	2.2200	.	1
	20-30cm	2.2100	.	1
	30-40cm	2.0100	.	1
	Total	2.1575	.09912	4
BCT	0-10cm	2.7100	.	1
	10-20cm	2.8400	.	1
	20-30cm	2.1300	.	1
	30-40cm	2.1100	.	1
	Total	2.4475	.38196	4
Total	0-10cm	2.2175	.34519	4
	10-20cm	2.2250	.43440	4
	20-30cm	2.0850	.11818	4
	30-40cm	2.0200	.06218	4
	Total	2.1369	.27075	16

Tests of Between-Subjects Effects

Dependent Variable: hydraulic conductivity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.730[a]	6	.122	2.962	.070
Intercept	73.060	1	73.060	1778.782	.000
Method	.607	3	.202	4.930	.027
Depth	.122	3	.041	.994	.439
Error	.370	9	.041		
Total	74.159	16			
Corrected Total	1.100	15			

a. R Squared = .664 (Adjusted R Squared = .440)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: hydraulic conductivity

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
2.137	.051	2.022	2.251

2. Land Prep. Method

Dependent Variable: hydraulic conductivity

Land Prep. Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
UNCULTVTD	1.965	.101	1.736	2.194
SBNT	1.978	.101	1.748	2.207
MCT	2.158	.101	1.928	2.387
BCT	2.448	.101	2.218	2.677

3. Soil Depth

Dependent Variable: hydraulic conductivity

Soil Depth	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
0-10cm	2.218	.101	1.988	2.447
10-20cm	2.225	.101	1.996	2.454
20-30cm	2.085	.101	1.856	2.314
30-40cm	2.020	.101	1.791	2.249

Post Hoc Tests

Land Prep. Method

Multiple Comparisons

Dependent Variable: hydraulic conductivity
LSD

(I) Land Prep. Method	(J) Land Prep. Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
UNCULTVTD	SBNT	-.0125	.14331	.932	-.3367	.3117
	MCT	-.1925	.14331	.212	-.5167	.1317
	BCT	-.4825*	.14331	.008	-.8067	-.1583
SBNT	UNCULTVTD	.0125	.14331	.932	-.3117	.3367
	MCT	-.1800	.14331	.241	-.5042	.1442
	BCT	-.4700*	.14331	.010	-.7942	-.1458
MCT	UNCULTVTD	.1925	.14331	.212	-.1317	.5167
	SBNT	.1800	.14331	.241	-.1442	.5042
	BCT	-.2900	.14331	.074	-.6142	.0342
BCT	UNCULTVTD	.4825*	.14331	.008	.1583	.8067
	SBNT	.4700*	.14331	.010	.1458	.7942
	MCT	.2900	.14331	.074	-.0342	.6142

Based on observed means.

*. The mean difference is significant at the .05 level.

Soil Depth

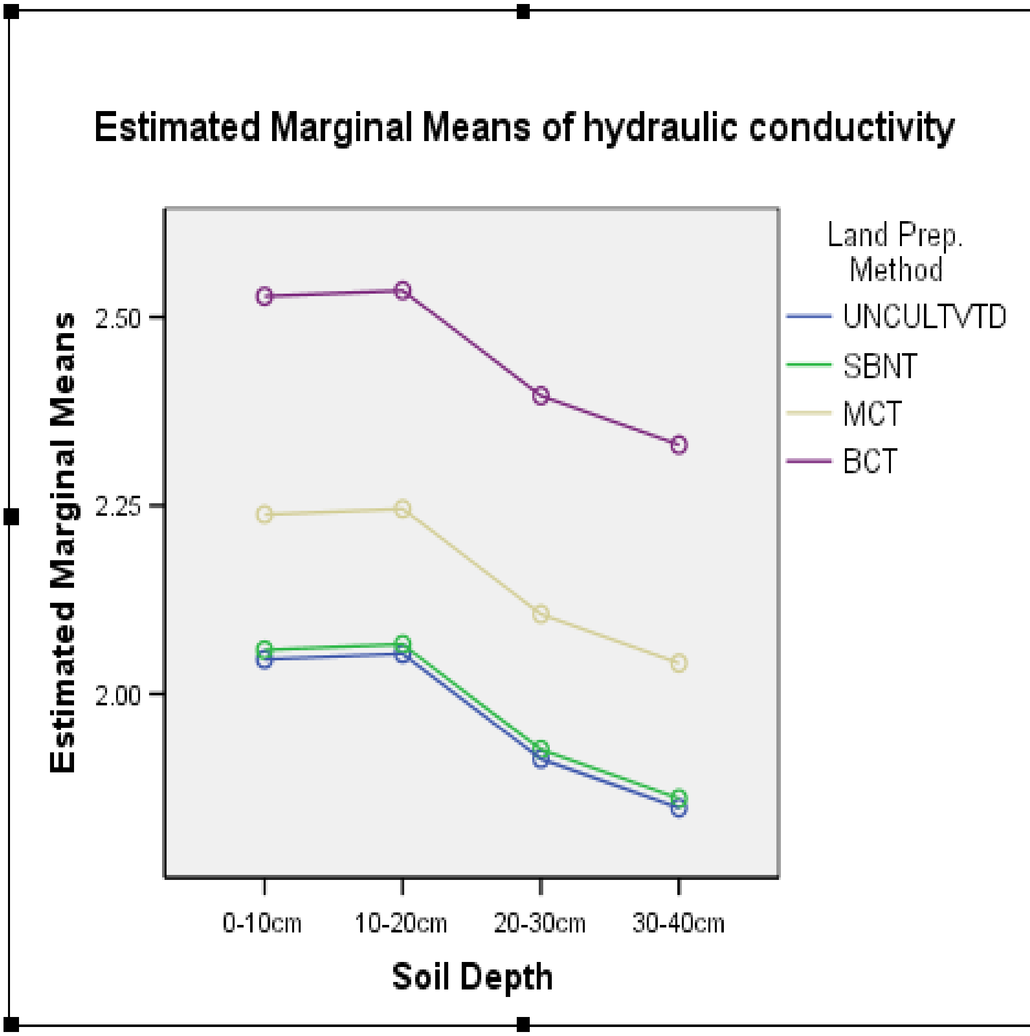
Multiple Comparisons

Dependent Variable: hydraulic conductivity
LSD

(I) Soil Depth	(J) Soil Depth	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0-10cm	10-20cm	-.0075	.14331	.959	-.3317	.3167
	20-30cm	.1325	.14331	.379	-.1917	.4567
	30-40cm	.1975	.14331	.201	-.1267	.5217
10-20cm	0-10cm	.0075	.14331	.959	-.3167	.3317
	20-30cm	.1400	.14331	.354	-.1842	.4642
	30-40cm	.2050	.14331	.186	-.1192	.5292
20-30cm	0-10cm	-.1325	.14331	.379	-.4567	.1917
	10-20cm	-.1400	.14331	.354	-.4642	.1842
	30-40cm	.0650	.14331	.661	-.2592	.3892
30-40cm	0-10cm	-.1975	.14331	.201	-.5217	.1267
	10-20cm	-.2050	.14331	.186	-.5292	.1192
	20-30cm	-.0650	.14331	.661	-.3892	.2592

Based on observed means.

Profile Plots



Appendix II: Univariate Analysis of Variance (Available water content)

```
[DataSet1] C:\Users\DUKE\Desktop\NEWEST\DATA SET 1.sav
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Between-Subjects Factors

		Value Label	N
Land Prep. Method	1	UNCULTVTD	4
	2	SBNT	4
	3	MCT	4
	4	BCT	4
Soil Depth	10	0-10cm	4
	20	10-20cm	4
	30	20-30cm	4
	40	30-40cm	4

Descriptive Statistics

Dependent Variable: Avail. Water Content

Land Prep. Method	Soil Depth	Mean	Std. Deviation	N
UNCULTVTD	0-10cm	8.5400	.	1
	10-20cm	5.5000	.	1
	20-30cm	7.6900	.	1
	30-40cm	8.2400	.	1
	Total	7.4925	1.37418	4
SBNT	0-10cm	8.7800	.	1
	10-20cm	8.9600	.	1
	20-30cm	8.1600	.	1
	30-40cm	8.2700	.	1
	Total	8.5425	.38785	4
MCT	0-10cm	8.2800	.	1
	10-20cm	7.9100	.	1
	20-30cm	7.8800	.	1
	30-40cm	9.1900	.	1
	Total	8.3150	.61104	4
BCT	0-10cm	7.4500	.	1
	10-20cm	6.5200	.	1
	20-30cm	7.7100	.	1
	30-40cm	7.5100	.	1
	Total	7.2975	.53012	4
Total	0-10cm	8.2625	.57887	4
	10-20cm	7.2225	1.52229	4
	20-30cm	7.8600	.21741	4
	30-40cm	8.3025	.68816	4
	Total	7.9119	.91410	16

Tests of Between-Subjects Effects

Dependent Variable: Avail. Water Content

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.468[a]	6	1.245	2.211	.137
Intercept	1001.564	1	1001.564	1779.432	.000
Method	4.454	3	1.485	2.638	.113
Depth	3.014	3	1.005	1.785	.220
Error	5.066	9	.563		
Total	1014.098	16			
Corrected Total	12.534	15			

a. R Squared = .596 (Adjusted R Squared = .326)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Avail. Water Content

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
7.912	.188	7.488	8.336

2. Land Prep. Method

Dependent Variable: Avail. Water Content

Land Prep. Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
UNCULTVTD	7.493	.375	6.644	8.341
SBNT	8.543	.375	7.694	9.391
MCT	8.315	.375	7.466	9.164
BCT	7.298	.375	6.449	8.146

3. Soil Depth

Dependent Variable: Avail. Water Content

Soil Depth	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
0-10cm	8.263	.375	7.414	9.111
10-20cm	7.223	.375	6.374	8.071
20-30cm	7.860	.375	7.011	8.709
30-40cm	8.303	.375	7.454	9.151

Post Hoc Tests

Land Prep. Method

Multiple Comparisons

Dependent Variable: Avail. Water Content
LSD

(I) Land Prep. Method	(J) Land Prep. Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
UNCULTVTD	SBNT	-1.0500	.53050	.079	-2.2501	.1501
	MCT	-.8225	.53050	.155	-2.0226	.3776
	BCT	.1950	.53050	.722	-1.0051	1.3951
SBNT	UNCULTVTD	1.0500	.53050	.079	-.1501	2.2501
	MCT	.2275	.53050	.678	-.9726	1.4276
	BCT	1.2450*	.53050	.044	.0449	2.4451
MCT	UNCULTVTD	.8225	.53050	.155	-.3776	2.0226
	SBNT	-.2275	.53050	.678	-1.4276	.9726
	BCT	1.0175	.53050	.087	-.1826	2.2176
BCT	UNCULTVTD	-.1950	.53050	.722	-1.3951	1.0051
	SBNT	-1.2450*	.53050	.044	-2.4451	-.0449
	MCT	-1.0175	.53050	.087	-2.2176	.1826

Based on observed means.

*. The mean difference is significant at the .05 level.

Soil Depth

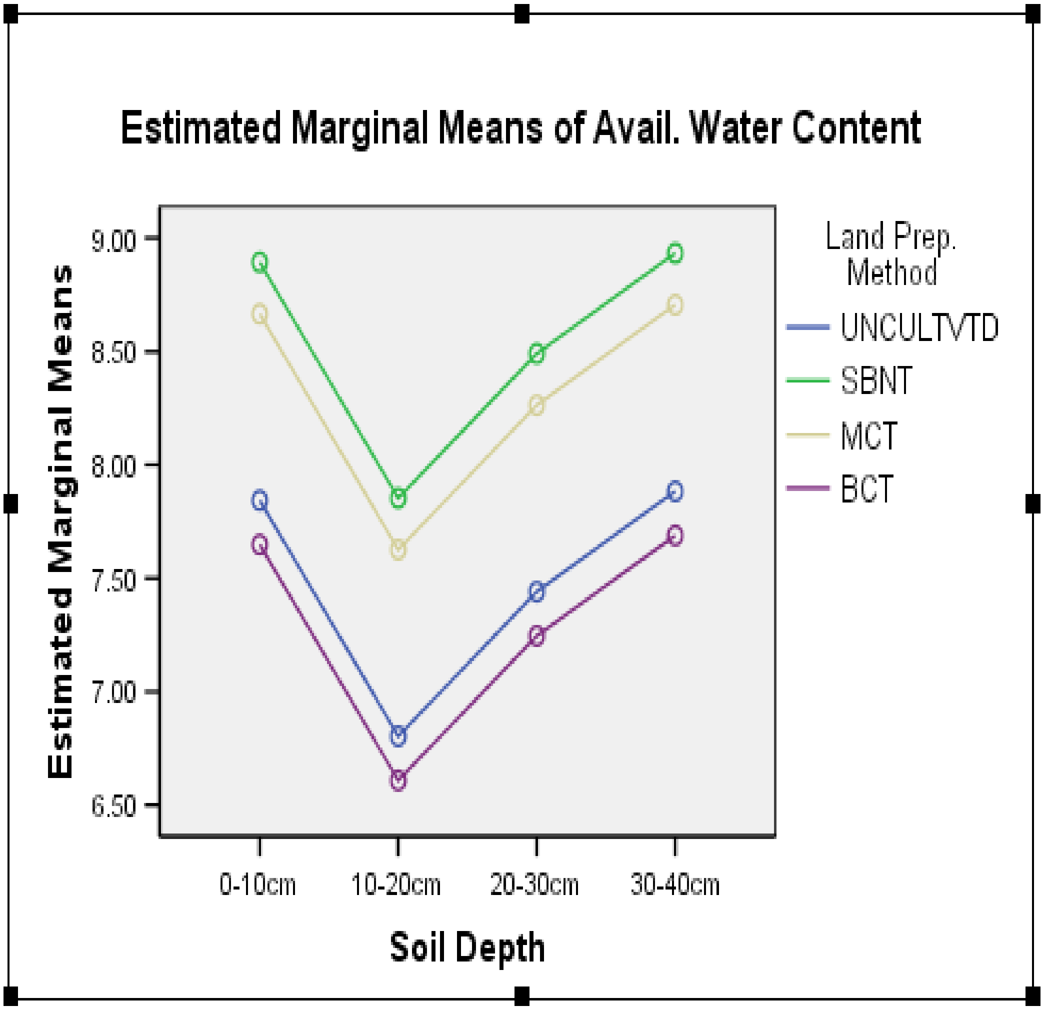
Multiple Comparisons

Dependent Variable: Avail. Water Content
LSD

(I) Soil Depth	(J) Soil Depth	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0-10cm	10-20cm	1.0400	.53050	.082	-.1601	2.2401
	20-30cm	.4025	.53050	.467	-.7976	1.6026
	30-40cm	-.0400	.53050	.942	-1.2401	1.1601
10-20cm	0-10cm	-1.0400	.53050	.082	-2.2401	.1601
	20-30cm	-.6375	.53050	.260	-1.8376	.5626
	30-40cm	-1.0800	.53050	.072	-2.2801	.1201
20-30cm	0-10cm	-.4025	.53050	.467	-1.6026	.7976
	10-20cm	.6375	.53050	.260	-.5626	1.8376
	30-40cm	-.4425	.53050	.426	-1.6426	.7576
30-40cm	0-10cm	.0400	.53050	.942	-1.1601	1.2401
	10-20cm	1.0800	.53050	.072	-.1201	2.2801
	20-30cm	.4425	.53050	.426	-.7576	1.6426

Based on observed means.

Profile Plots



Appendix III: Univariate Analysis of Variance (Dry Bulk Density)

[DataSet1] C:\Users\DUKE\Desktop\NEWEST\DATA SET 1.sav

Between-Subjects Factors

		Value Label	N
Land Prep. Method	1	UNCULTVTD	4
	2	SBNT	4
	3	MCT	4
	4	BCT	4
Soil Depth	10	0-10cm	4
	20	10-20cm	4
	30	20-30cm	4
	40	30-40cm	4

Descriptive Statistics

Dependent Variable: Dry bulk density

Land Prep. Method	Soil Depth	Mean	Std. Deviation	N
UNCULTVTD	0-10cm	1.4300	.	1
	10-20cm	1.4500	.	1
	20-30cm	1.5500	.	1
	30-40cm	1.5800	.	1
	Total	1.5025	.07365	4
SBNT	0-10cm	1.3100	.	1
	10-20cm	1.5600	.	1
	20-30cm	1.5700	.	1
	30-40cm	1.5900	.	1
	Total	1.5075	.13226	4
MCT	0-10cm	1.3000	.	1
	10-20cm	1.3700	.	1
	20-30cm	1.5200	.	1
	30-40cm	1.6000	.	1
	Total	1.4475	.13696	4
BCT	0-10cm	1.0300	.	1
	10-20cm	1.1600	.	1
	20-30cm	1.3900	.	1
	30-40cm	1.4700	.	1
	Total	1.2625	.20320	4
Total	0-10cm	1.2675	.16899	4
	10-20cm	1.3850	.16902	4
	20-30cm	1.5075	.08098	4
	30-40cm	1.5600	.06055	4
	Total	1.4300	.16480	16

Tests of Between-Subjects Effects

Dependent Variable: Dry bulk density

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.364[a]	6	.061	12.532	.001
Intercept	32.718	1	32.718	6761.552	.000
Method	.159	3	.053	10.918	.002
Depth	.205	3	.068	14.146	.001
Error	.044	9	.005		
Total	33.126	16			
Corrected Total	.407	15			

a. R Squared = .893 (Adjusted R Squared = .822)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: Dry bulk density

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
1.430	.017	1.391	1.469

2. Land Prep. Method

Dependent Variable: Dry bulk density

Land Prep. Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
UNCULTVTD	1.503	.035	1.424	1.581
SBNT	1.508	.035	1.429	1.586
MCT	1.448	.035	1.369	1.526
BCT	1.263	.035	1.184	1.341

3. Soil Depth

Dependent Variable: Dry bulk density

Soil Depth	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
0-10cm	1.268	.035	1.189	1.346
10-20cm	1.385	.035	1.306	1.464
20-30cm	1.508	.035	1.429	1.586
30-40cm	1.560	.035	1.481	1.639

Post Hoc Tests

Land Prep. Method

Multiple Comparisons

Dependent Variable: Dry bulk density
LSD

(I) Land Prep. Method	(J) Land Prep. Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
UNCULTVTD	SBNT	-.0050	.04919	.921	-.1163	.1063
	MCT	.0550	.04919	.292	-.0563	.1663
	BCT	.2400*	.04919	.001	.1287	.3513
SBNT	UNCULTVTD	.0050	.04919	.921	-.1063	.1163
	MCT	.0600	.04919	.254	-.0513	.1713
	BCT	.2450*	.04919	.001	.1337	.3563
MCT	UNCULTVTD	-.0550	.04919	.292	-.1663	.0563
	SBNT	-.0600	.04919	.254	-.1713	.0513
	BCT	.1850*	.04919	.004	.0737	.2963
BCT	UNCULTVTD	-.2400*	.04919	.001	-.3513	-.1287
	SBNT	-.2450*	.04919	.001	-.3563	-.1337
	MCT	-.1850*	.04919	.004	-.2963	-.0737

Based on observed means.

*. The mean difference is significant at the .05 level.

Soil Depth

Multiple Comparisons

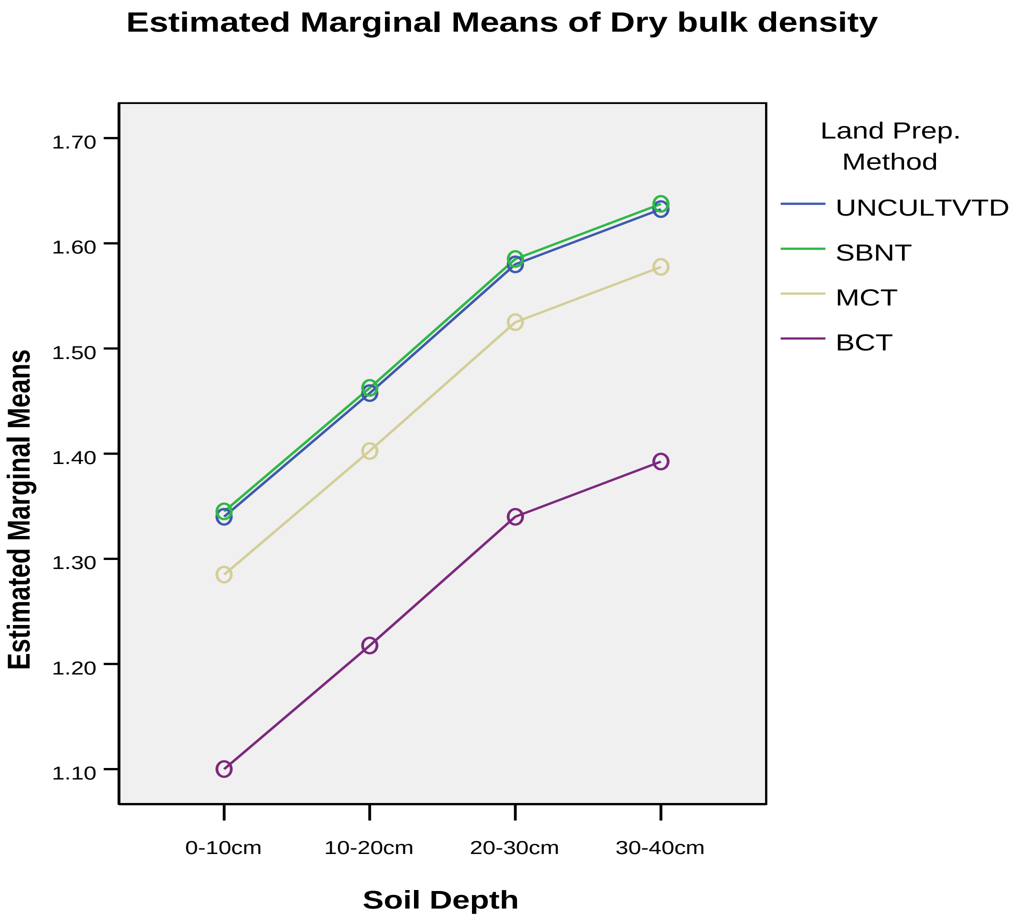
Dependent Variable: Dry bulk density
LSD

(I) Soil Depth	(J) Soil Depth	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0-10cm	10-20cm	-.1175*	.04919	.041	-.2288	-.0062
	20-30cm	-.2400*	.04919	.001	-.3513	-.1287
	30-40cm	-.2925*	.04919	.000	-.4038	-.1812
10-20cm	0-10cm	.1175*	.04919	.041	.0062	.2288
	20-30cm	-.1225*	.04919	.034	-.2338	-.0112
	30-40cm	-.1750*	.04919	.006	-.2863	-.0637
20-30cm	0-10cm	.2400*	.04919	.001	.1287	.3513
	10-20cm	.1225*	.04919	.034	.0112	.2338
	30-40cm	-.0525	.04919	.314	-.1638	.0588
30-40cm	0-10cm	.2925*	.04919	.000	.1812	.4038
	10-20cm	.1750*	.04919	.006	.0637	.2863
	20-30cm	.0525	.04919	.314	-.0588	.1638

Based on observed means.

*. The mean difference is significant at the .05 level.

Profile Plots



Appendix IV: Univariate Analysis of Variance (Porosity)

[DataSet1] C:\Users\DUKE\Desktop\NEWEST\DATA SET 1.sav

Between-Subjects Factors

		Value Label	N
Land Prep. Method	1	UNCULTVTD	4
	2	SBNT	4
	3	MCT	4
	4	BCT	4
Soil Depth	10	0-10cm	4
	20	10-20cm	4
	30	20-30cm	4
	40	30-40cm	4

Descriptive Statistics

Dependent Variable: porosity

Land Prep. Method	Soil Depth	Mean	Std. Deviation	N
UNCULTVTD	0-10cm	45.9300	.	1
	10-20cm	45.3300	.	1
	20-30cm	41.6400	.	1
	30-40cm	40.4400	.	1
	Total	43.3350	2.70605	4
SBNT	0-10cm	50.6600	.	1
	10-20cm	41.1500	.	1
	20-30cm	40.7700	.	1
	30-40cm	39.9800	.	1
	Total	43.1400	5.03696	4
MCT	0-10cm	50.9400	.	1
	10-20cm	48.2100	.	1
	20-30cm	42.6100	.	1
	30-40cm	39.4500	.	1
	Total	45.3025	5.21972	4
BCT	0-10cm	61.1900	.	1
	10-20cm	56.1900	.	1
	20-30cm	47.5800	.	1
	30-40cm	44.4700	.	1
	Total	52.3575	7.69715	4
Total	0-10cm	52.1800	6.43145	4
	10-20cm	47.7200	6.34713	4
	20-30cm	43.1500	3.04746	4
	30-40cm	41.0850	2.29263	4
	Total	46.0338	6.23047	16

Tests of Between-Subjects Effects

Dependent Variable: porosity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	518.430[a]	6	86.405	12.179	.001
Intercept	33905.698	1	33905.698	4779.057	.000
Method	224.726	3	74.909	10.559	.003
Depth	293.704	3	97.901	13.799	.001
Error	63.852	9	7.095		
Total	34487.980	16			
Corrected Total	582.282	15			

a. R Squared = .890 (Adjusted R Squared = .817)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: porosity

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
46.034	.666	44.527	47.540

2. Land Prep. Method

Dependent Variable: porosity

Land Prep. Method	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
UNCULTVTD	43.335	1.332	40.322	46.348
SBNT	43.140	1.332	40.127	46.153
MCT	45.303	1.332	42.290	48.315
BCT	52.358	1.332	49.345	55.370

3. Soil Depth

Dependent Variable: porosity

Soil Depth	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
0-10cm	52.180	1.332	49.167	55.193
10-20cm	47.720	1.332	44.707	50.733
20-30cm	43.150	1.332	40.137	46.163
30-40cm	41.085	1.332	38.072	44.098

Post Hoc Tests

Land Prep. Method

Multiple Comparisons

Dependent Variable: porosity
LSD

(I) Land Prep. Method	(J) Land Prep. Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
UNCULTVTD	SBNT	.1950	1.88343	.920	-4.0656	4.4556
	MCT	-1.9675	1.88343	.323	-6.2281	2.2931
	BCT	-9.0225*	1.88343	.001	-13.2831	-4.7619
SBNT	UNCULTVTD	-.1950	1.88343	.920	-4.4556	4.0656
	MCT	-2.1625	1.88343	.281	-6.4231	2.0981
	BCT	-9.2175*	1.88343	.001	-13.4781	-4.9569
MCT	UNCULTVTD	1.9675	1.88343	.323	-2.2931	6.2281
	SBNT	2.1625	1.88343	.281	-2.0981	6.4231
	BCT	-7.0550*	1.88343	.005	-11.3156	-2.7944
BCT	UNCULTVTD	9.0225*	1.88343	.001	4.7619	13.2831
	SBNT	9.2175*	1.88343	.001	4.9569	13.4781
	MCT	7.0550*	1.88343	.005	2.7944	11.3156

Based on observed means.

*. The mean difference is significant at the .05 level.

Soil Depth

Multiple Comparisons

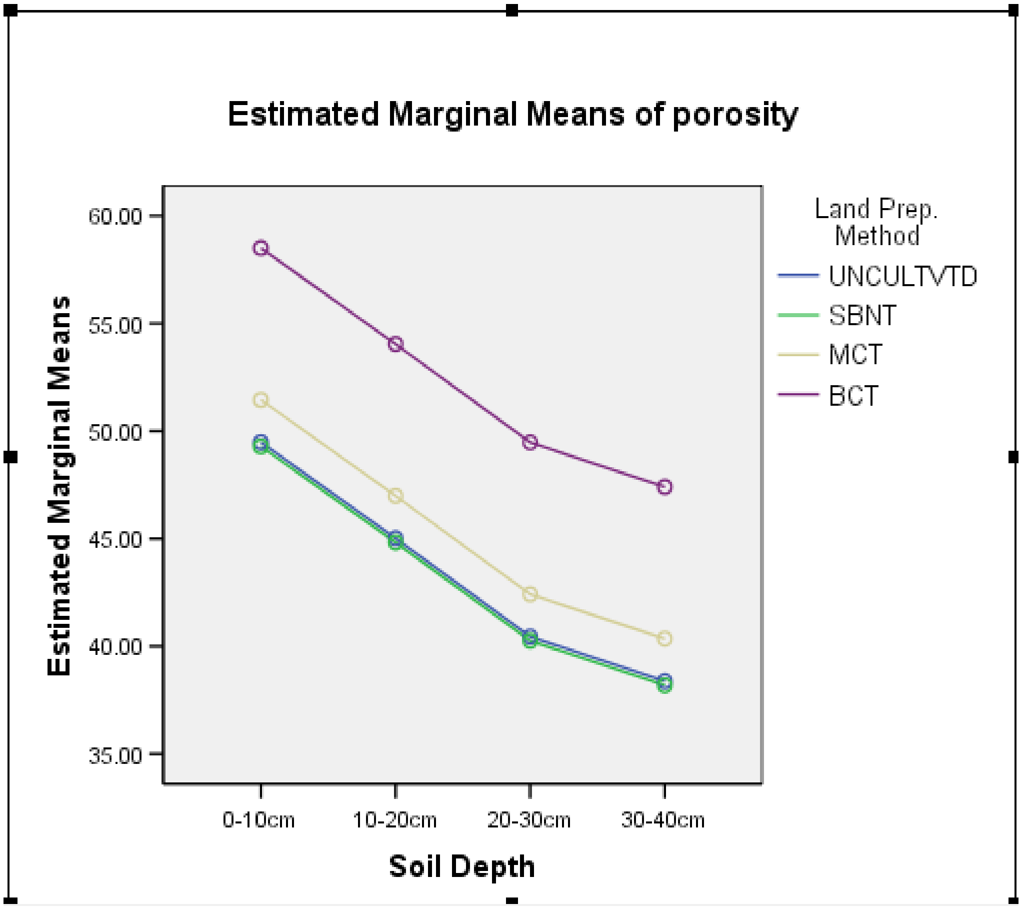
Dependent Variable: porosity
LSD

(I) Soil Depth	(J) Soil Depth	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
0-10cm	10-20cm	4.4600*	1.88343	.042	.1994	8.7206
	20-30cm	9.0300*	1.88343	.001	4.7694	13.2906
	30-40cm	11.0950*	1.88343	.000	6.8344	15.3556
10-20cm	0-10cm	-4.4600*	1.88343	.042	-8.7206	-.1994
	20-30cm	4.5700*	1.88343	.038	.3094	8.8306
	30-40cm	6.6350*	1.88343	.006	2.3744	10.8956
20-30cm	0-10cm	-9.0300*	1.88343	.001	-13.2906	-4.7694
	10-20cm	-4.5700*	1.88343	.038	-8.8306	-.3094
	30-40cm	2.0650	1.88343	.301	-2.1956	6.3256
30-40cm	0-10cm	-11.0950*	1.88343	.000	-15.3556	-6.8344
	10-20cm	-6.6350*	1.88343	.006	-10.8956	-2.3744
	20-30cm	-2.0650	1.88343	.301	-6.3256	2.1956

Based on observed means.

*. The mean difference is significant at the .05 level.

Profile Plots



Appendix V: Regression Summary Output of Dry Bulk Density Vrs Hydraulic Conductivity

Regression Statistics	
Multiple R	0.821691
R Square	0.675175
Adjusted R Square	0.651974
Standard Error	0.159723
Observations	16

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.742385	0.742385	29.10017	9.46E-05
Residual	14	0.357159	0.025511		
Total	15	1.099544			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4.067431	0.360099	11.29533	2.03E-08	3.295097	4.839766	3.295097	4.839766
X Variable 1	-1.34976	0.250213	-5.39446	9.46E-05	-1.88642	-0.81311	-1.88642	-0.81311

RESIDUAL OUTPUT

Observation	*Predicted 1.93*	*Residuals*	*Standard Residuals*
1	2.125379	-0.23538	-1.57407
2	1.99372	0.07628	0.510112
3	1.950975	0.019025	0.127226
4	2.31263	-0.27263	-1.82318
5	1.975536	-0.02554	-0.17077
6	1.962052	-0.03205	-0.21435
7	1.935085	0.054915	0.367238
8	2.326088	-0.13609	-0.91007
9	2.228301	-0.0083	-0.05551
10	2.028268	0.181732	1.215314
11	1.915257	0.094743	0.633586
12	2.690174	0.019826	0.132582
13	2.514886	0.325114	2.174166
14	2.20476	-0.07476	-0.49995
15	2.09689	0.01311	0.087673

PROBABILITY OUTPUT

Percentile	*1.93*
3.333333	1.89
10	1.93
16.66667	1.95
23.33333	1.97
30	1.99
36.66667	2.01
43.33333	2.04
50	2.07
56.66667	2.11
63.33333	2.13
70	2.19
76.66667	2.21
83.33333	2.22
90	2.71
96.66667	2.84

Appendix VI: Regression Summary Output of Soil Porosity Vrs Hydraulic Conductivity

Regression Statistics	
Multiple R	0.82009
R Square	0.672547
Adjusted R Square	0.649158
Standard Error	0.160368
Observations	16

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.739495	0.739495	28.75426	0.0001
Residual	14	0.360049	0.025718		
Total	15	1.099544			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.496438	0.308536	1.609011	0.129924	-0.16531	1.158183	-0.16531	1.158183
X Variable 1	0.035636	0.006646	5.3623	0.0001	0.021382	0.049889	0.021382	0.049889

RESIDUAL OUTPUT

Observation	*Predicted 1.93*	*Residuals*	*Standard Residuals*
1	2.125379	-0.23538	-1.57407
2	1.99372	0.07628	0.510112
3	1.950975	0.019025	0.127226
4	2.31263	-0.27263	-1.82318
5	1.975536	-0.02554	-0.17077
6	1.962052	-0.03205	-0.21435
7	1.935085	0.054915	0.367238
8	2.326088	-0.13609	-0.91007
9	2.228301	-0.0083	-0.05551
10	2.028268	0.181732	1.215314
11	1.915257	0.094743	0.633586
12	2.690174	0.019826	0.132582
13	2.514886	0.325114	2.174166
14	2.20476	-0.07476	-0.49995
15	2.09689	0.01311	0.087673

PROBABILITY OUTPUT

Percentile	*1.93*
3.333333	1.89
10	1.93
16.66667	1.95
23.33333	1.97
30	1.99
36.66667	2.01
43.33333	2.04
50	2.07
56.66667	2.11
63.33333	2.13
70	2.19
76.66667	2.21
83.33333	2.22
90	2.71
96.66667	2.84

Appendix VII: Data Collection and Analysis for Land Preparations in Odumasua, April 20-23, 2013

SAMPLE	CAN WT	WET + CAN	DRY +CAN	WET - DRY	DRY SOIL	CORE VOL	DB DENSITY	POROSITY
PIT 1 -10	120.57	292.39	268.72	23.67	148.15	99.79	1.48	43.97
PIT 1 -20	127.42	300.69	264.03	36.66	136.61	99.79	1.37	48.34
PIT 1 - 30	125.13	301.17	285.24	15.93	160.11	99.79	1.60	39.45
PIT 1 - 40	123.01	294.55	282.52	12.03	159.51	99.79	1.60	39.68
PIT 1 -40	127.41	301.86	288.80	13.06	161.39	99.79	1.62	38.97
PIT 2 - 10	27.63	177.42	155.65	21.77	128.02	99.79	1.28	51.59
PIT 2 - 20	28.16	209.16	165.76	43.40	137.60	99.79	1.38	47.96
PIT 2 - 30	25.95	196.67	178.91	17.76	152.96	99.79	1.53	42.16
PIT 2 - 40	30.48	215.38	192.41	22.97	161.93	99.79	1.62	38.76
PIT 3 - 10	31.49	156.06	144.49	11.57	113.00	99.79	1.13	57.27
PIT 3 - 20	31.98	188.29	168.65	19.64	136.67	99.79	1.37	48.32
PIT 3 - 30	25.58	175.23	167.80	7.43	142.22	99.79	1.43	46.22
PIT 3 - 40	31.64	214.98	190.58	24.40	158.94	99.79	1.59	39.89
PIT 4- 10	29.74	179.36	164.38	14.98	134.64	99.79	1.35	49.08
PIT 4 - 20	25.19	209.41	190.76	18.65	165.57	99.79	1.66	37.39
PIT 4 - 30	31.52	211.03	194.07	16.96	162.55	99.79	1.63	38.53
PIT 4 - 40	29.59	199.65	184.49	15.16	154.90	99.79	1.55	41.42
PIT 5 - 10	25.64	158.97	144.10	14.87	118.46	99.79	1.19	55.20
PIT 5 - 20	25.76	173.95	158.80	15.15	133.04	99.79	1.33	49.69
PIT 5 - 30	32.58	208.67	193.11	15.56	160.53	99.79	1.61	39.29
PIT 5 - 40	26.05	208.50	193.46	15.04	167.41	99.79	1.68	36.69
PIT 6 - 10	26.98	190.25	171.69	18.56	144.71	99.79	1.45	45.28
PIT 6 - 20	30.90	233.01	209.22	23.79	178.32	99.79	1.79	32.56
PIT 6 - 30	31.76	217.77	197.55	20.22	165.79	99.79	1.66	37.30
PIT 6 - 40	31.24	209.43	190.15	19.28	158.91	99.79	1.59	39.91
PIT 7 - 10	25.97	206.50	173.17	33.33	147.20	99.79	1.48	44.33
PIT 8 - 10	30.46	181.91	173.91	8.00	143.45	99.79	1.44	45.75
PIT 8 - 20	24.78	170.19	175.31	-5.12	150.53	99.79	1.51	43.07
PIT 8 - 30	31.44	202.18	185.18	17.00	153.74	99.79	1.54	41.86

PIT 8 - 40	25.99	198.76	186.01	12.75	160.02	99.79	1.60	39.49
PIT 9 - 10	29.82	183.81	170.89	12.92	141.07	99.79	1.41	46.65
PIT 9 - 20	25.48	186.10	168.04	18.06	142.56	99.79	1.43	46.09
PIT 9 - 30	31.43	204.64	186.69	17.95	155.26	99.79	1.56	41.29
PIT 9 - 40	31.71	195.68	187.57	8.11	155.86	99.79	1.56	41.06
PIT 10 - 10	24.53	172.30	168.96	3.34	144.43	99.79	1.45	45.38
PIT 10 - 20	31.41	189.85	172.05	17.80	140.64	99.79	1.41	46.81
PIT 10 - 30	29.87	201.03	183.83	17.20	153.96	99.79	1.54	41.78
PIT 10 - 40	32.05	203.34	188.62	14.72	156.57	99.79	1.57	40.79
PIT 11 - 10	26.56	177.01	157.03	19.98	130.47	99.79	1.31	50.66
PIT 11 - 20	24.68	197.24	180.30	16.94	155.62	99.79	1.56	41.15
PIT 11 - 30	28.99	214.78	185.62	29.16	156.63	99.79	1.57	40.77
PIT 11 - 40	25.14	193.65	183.85	9.80	158.71	99.79	1.59	39.98
PIT 12 - 10	26.08	141.25	128.70	12.55	102.62	99.79	1.03	61.19
PIT 12 - 20	25.78	160.28	141.63	18.65	115.85	99.79	1.16	56.19
PIT 12 - 30	25.64	198.13	164.26	33.87	138.62	99.79	1.39	47.58
PIT 12 - 40	25.56	204.78	172.40	32.38	146.84	99.79	1.47	44.47