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**UNIVERSITY OF GHANA**  
**SCHOOL OF PHYSICAL AND MATHEMATICAL SCIENCES**  
**DEPARTMENT OF CHEMISTRY**



**SOIL QUALITY OF SELECTED FARMS IN ASESEWA IN THE EASTERN REGION**

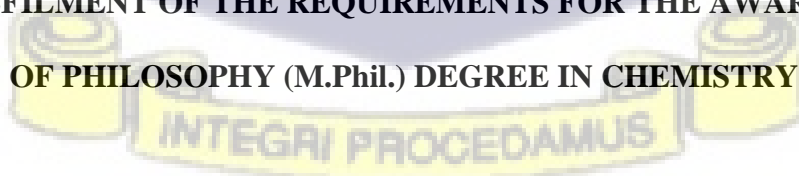
**OF GHANA**

**PRESENTED BY**

**EMMANUEL TAWIAH ADU**

**(10804357)**

**A DISSERTATION SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN  
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER  
OF PHILOSOPHY (M.Phil.) DEGREE IN CHEMISTRY.**



**SEPTEMBER, 2021.**

**DECLARATION**

I hereby declare that apart from the sources acknowledged as contributions in the text, this very work comprises the results of my research work and for that matter it has not been admitted in part or whole to any universities across the globe.



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.....27/09/21.....

Emmanuel Tawiah Adu

Date

(Student)



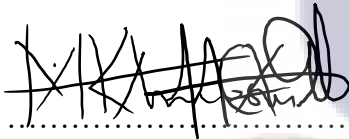
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.....27/09/21.....

Prof. Augustine K. Donkor

Date

(Supervisor)



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.....27/09/2021.....

Dr. Michael K. Ainooson

Date

(Principal Supervisor)



**DEDICATION**

This work is dedicated to YAHWEH ELOHIM for his divine protection.

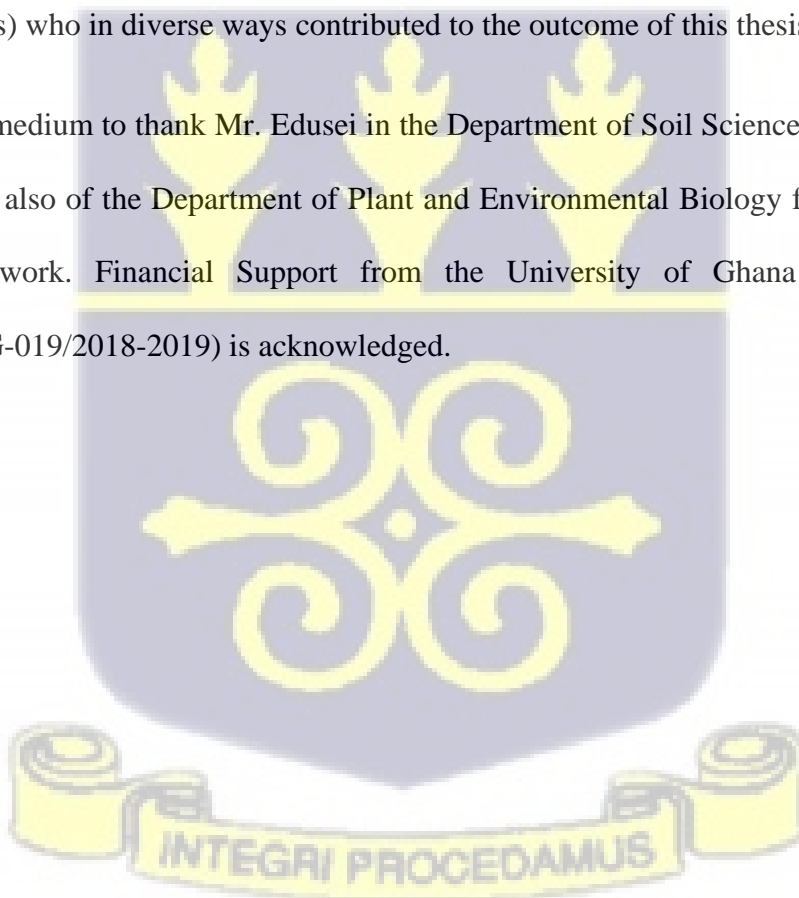


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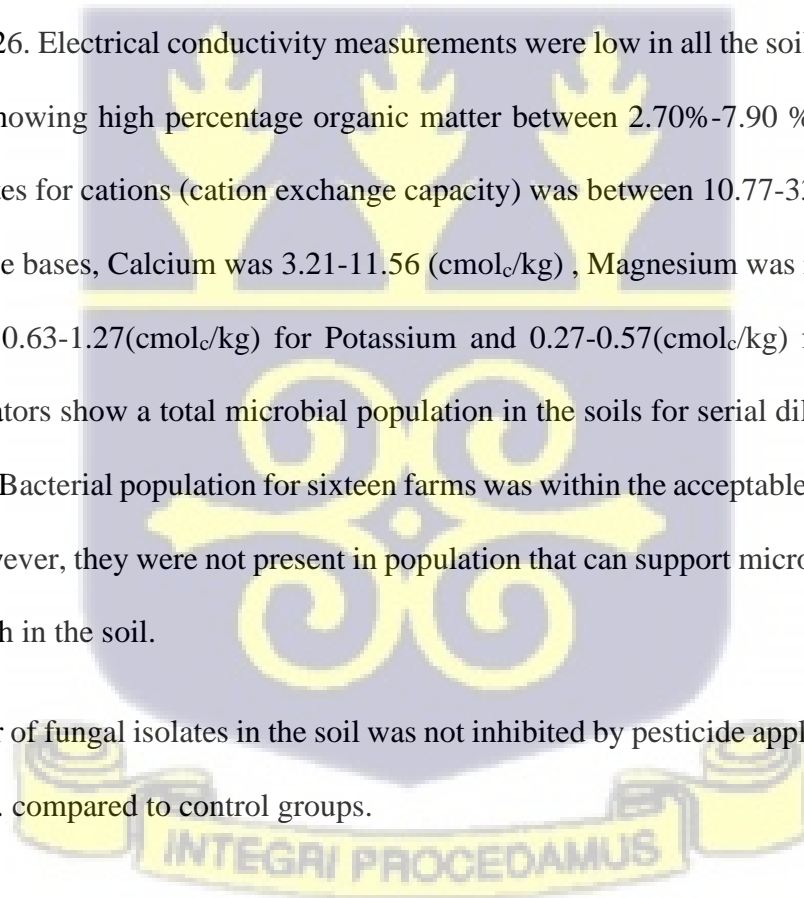
Let me use this medium to thank Mr. Edusei in the Department of Soil Sciences and Dr. Michael Wiafe-Kwagyan also of the Department of Plant and Environmental Biology for assisting me in the laboratory work. Financial Support from the University of Ghana Research Fund, (UGRF/11/MDG-019/2018-2019) is acknowledged.



## ABSTRACT

Increasing demand for food supply, coupled with the financial needs of smallholder farmers has triggered the use of farm management practices that threaten the quality of agricultural soils. These practices include annual bushfire for clearing the land, yearly plowing and the indiscriminate application of pesticides. These practices have the propensity of reducing the soil quality. Soil quality indicators provide essential knowledge on the capacity of soils to function within the ecosystem and support plant growth. This work studied the soil quality status of farms from the Upper Manya Krobo District, Asesewa by measuring their physical, chemical and biological indicators. The results for the chemical indicators show strongly acidic to neutral soils with pH range of 4.88-7.26. Electrical conductivity measurements were low in all the soils 0.043-0.317 (dS /m) with soils showing high percentage organic matter between 2.70%-7.90 %. The number of exchangeable sites for cations (cation exchange capacity) was between 10.77-33.31(cmol(+)/Kg). For exchangeable bases, Calcium was 3.21-11.56 (cmol<sub>c</sub>/kg) , Magnesium was in a range of 0.69-3.12(cmol<sub>c</sub>/kg), 0.63-1.27(cmol<sub>c</sub>/kg) for Potassium and 0.27-0.57(cmol<sub>c</sub>/kg) for Sodium. The biological indicators show a total microbial population in the soils for serial dilutions of 10<sup>-4</sup> and 10<sup>-5</sup>for bacteria. Bacterial population for sixteen farms was within the acceptable range in pesticide treated soils however, they were not present in population that can support microbial activities and processes enough in the soil.

A great number of fungal isolates in the soil was not inhibited by pesticide application especially, *Streptomyces sp.* compared to control groups.



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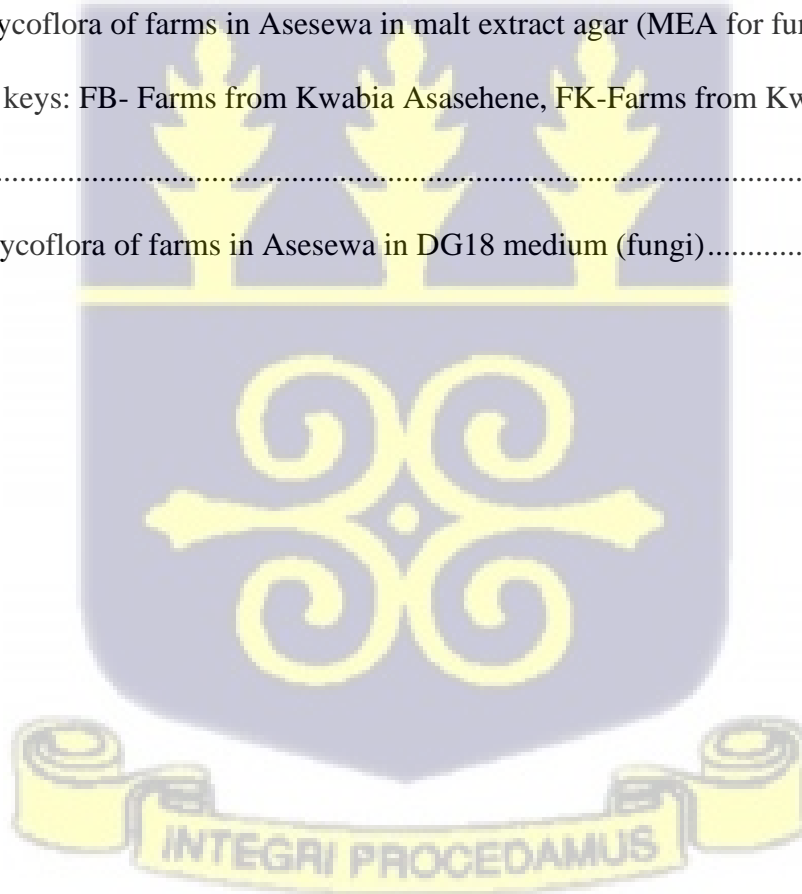
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**LIST OF ABBREVIATIONS**

CEC..... Cation Exchange Capacity

EC.....Electrical Conductivity

OM.....Organic Matter

OC..... Organic Carbon

MoFA..... Ministry of Food and Agriculture

USDA..... United States Department of Agriculture

CFU..... Colony Forming Unit

SOC..... Soil Organic Carbon

TDS..... Total Data Set

MDS..... Minimum Data Set

SQ.....Soil Quality

TFTC..... Too Few To Count

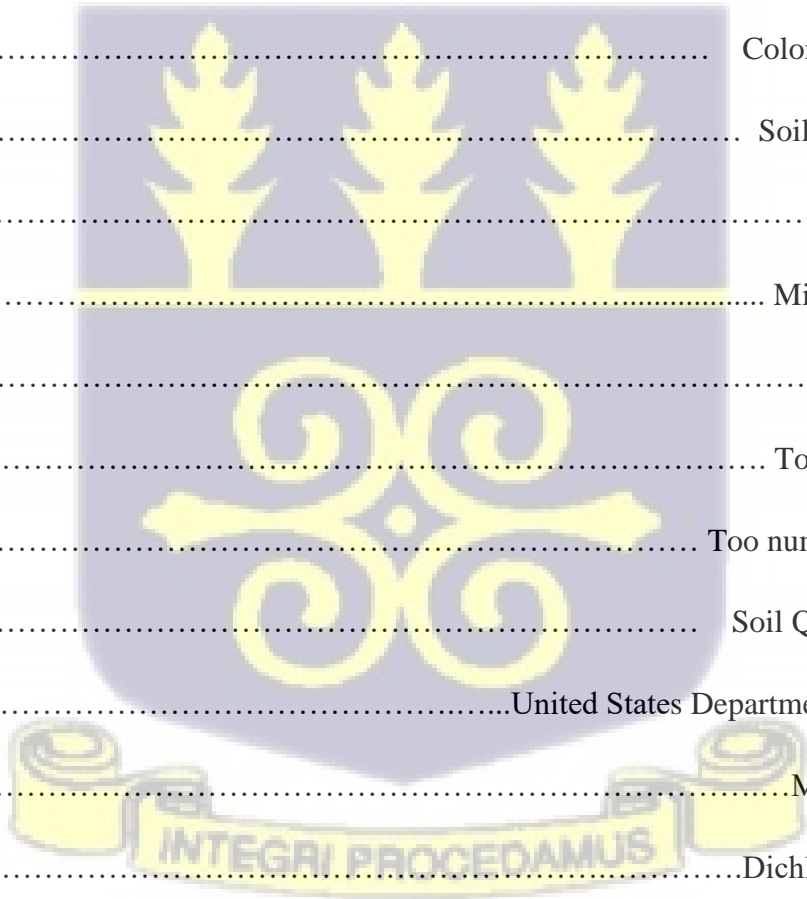
TNTC..... Too numerous To Count

SQL..... Soil Quality Indicators

USDA.....United States Department of Agriculture

MEA..... Malt Extract Agar

DG18.....Dichloran Glycerol 18



## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background

The survival of humans on earth has been influenced by the lifecycle of both the living and non-living components of the environment. To support human life, there is an interdependence between plants, animals and their ecosystem. Since antiquity, agriculture has existed as a very essential field in the growth of living things especially humans as it is essential for the production of food for survival as well as the creation of pertinent jobs for humans. Agriculture serves as the primary source of livelihood to an estimated two million people thus a vital economic activity (Alavanja, 2009). In Ghana, the sector contributes to about 40% of the gross domestic product serving as the highest sources of jobs for about 60% of the population (MoFA/SRID, 2011).

With increasing growth of population all over the world, the dependence on agriculture for subsistence is even higher while current situation such as climatic changes has affected the process of Agriculture, as well as poor land usage system, have led to large areas of land infertile or at the mercy of fertilizers to boost their yield or produce to serve the ever-growing population. In sub-Saharan Africa, it is estimated that about 15% of the population currently live in locations that have high food insecurities as a result of soil degradations from unsafe agricultural practices of which Ghana is no exception (Bremner, 2012).

It is projected according to Montpellier (2013), that by 2050, food insecurity globally would affect some 9 billion people should nothing be done about the issue, for the fact that soil quality is being impacted. Soils are important as they serve as medium to produce food and fiber for human utilization. Currently, sustainable and productive agriculture are highly related to soil quality. Soil quality refers to the capacity of soil to function within ecosystem boundaries to sustain biological

productivity, maintain environmental quality and, promote plant and animal health. Today, sustainable and productive agriculture are highly related to soil quality (Mulat et al. 2021).

Soil degradation practices are known as major factors affecting agricultural production as they wear off the topsoil to the subsoil which is an essential location for plants' soil nutrients and soil microorganisms. Common degradation practices include but are not limited to mining, soil erosion arising from loss of vegetative cover, deforestation, low assurance of land tenure, overgrazing, bush burning among others. Other factors affecting the agricultural industry are the lack of government initiative to cover safe agriculture and policies to conserve soil and water quality in the Upper Manya Krobo District. These have put the global population at a high risk of food shortages and related challenges.

In the wake to overcome the fore mentioned challenges, there has been an intensification policy to boost agricultural productivity to meet the growing demands of the population. However, it is impossible to achieve this goal if there are no soil quality indicators to show the quality of the soil for crop production.

Soil quality indicators provide information on the physical, chemical, and biological conditions of the soil which inform the farmer on the capacity of the soil to support the cultivation of a type of crop and the yield to expect from a particular soil type. In context, high soil quality leads to higher food crops productivity. Examples of soil quality parameters include soil particle size, moisture content, pH, organic matter content, cation exchange capacity, electrical conductivity, and microbial population. However, in the determination of soil quality, no single parameter can be used to ascertain the complete health of the soil as a result of the complex nature of the soil system.

In Ghana, the Eastern Region serves as one of the major hubs for the production of food crops from agricultural activities. With the majority of the population residing in Accra, the capital,

where there are few agricultural activities to feed the ever-growing population, most of the food crops come from neighboring regions of which the Eastern Region is a primary source.

Therefore, a shortage in the food production in the Eastern Region impacts the entire country. Hence, the call for pragmatic efforts to evaluate soil quality as there exists no data on such, within the farming communities in Asesewa which is popular for the production of many of the food crops. Hence, the study examined the physical, chemical and biological indicators of soils from selected farms within the Upper Manya Krobo District in the Eastern Region and the likely interventions for proper land use in the Upper Manya Krobo District to support the national goal of Planting for Food and Jobs in Ghana.

## **1.2 Problem Statement**

The increased demand for food crops to meet the national and global call has resulted in the use of numerous farm management practices which threaten the quality of the soil, chiefly among them is the uncontrolled application of fertilizers and pesticides mainly with the aim of boosting productivity. This has resulted in a rapid decline in the quality of the soil and subsequently a low crop production over seasons. To solve this challenge there is the need for regular observation of how farming practices impact the soil and the agro-ecosystem which are dependent on the knowledge of the farmer. More often than not, farmers use touch, sight and smell easily as parameters for quantitative assessment of soil quality locally (Bicalho and Peixoto, 2016), however, these are inappropriate methods and provide little information on the chemical and biological properties of the soil.

Ghana is faced with a challenge of overly dependence of fertilizers for farming and the use of pesticides, some of which provide adverse environmental conditions. Upper Manya Krobo District serves as home for a lot of crop production farm lands in Ghana. Though a major crop production site, they are confronted with the decline in food crop productivity regardless of the incessant application of fertilizers, which is an indication of soil degradation. Without soil quality studies being conducted, the productivity of the farm lands will remain the same which is a threat to food security locally.

### **1.3 Justification**

In recent years, the waning in agricultural produce in most parts of the world especially in Ghana is the agricultural sector, the key contributor to the countries revenue which has caused much harm due to the growing concern of food scarcity. This has resulted in the overreliance of fertilizer and pesticides while others resort to unsafe farming practices just to boost their farm produce.

This has in consequence left a huge impact on the quality of farm lands and the environment as most lands are faced with low nutrient content and microorganism activities hence their inability to self-fallow. This present situation requires a continuous examination of most farm lands to ascertain their soil quality indicators.

The farm lands in the Upper Manya Krobo District presents no different case, recognized as a contributor of agricultural supplies for the capital (Accra) and the Eastern Region and presently confronted with a continuous decline in production over the years. With no information documented on the quality of the soils for farming, it is of much essence that a study be conducted on the soils in that regard to ascertain the state of the soil. Thus, the information obtained will help

the farm manager with decisions on the growth of a specific type of crop in the right soil. Hence this work will serve as baseline values for other future monitoring studies which will be conducted on farm lands.

#### **1.4 Aim**

The aim of the study is to assess the soil quality of some selected farms in Asesewa (Upper Manya Krobo District) in the Eastern Region and its surroundings.

#### **1.5 Objectives**

1. To identify and sample soils from the various farm lands across the Asesewa District and its surroundings
2. To determine the physicochemical properties of the sampled farm soils.
3. To determine the microbial population present in the soil samples.
4. To evaluate the soil quality index based on the soil indicators

#### **1.6 Organization of the study**

Chapter one covers the introduction which involves the background of this study, the problem statement, objectives and justification. Chapter two deals with the literature review of previous studies. Chapter three gives the details of the methods used in solving the problem. Chapter four outlines the results and discussion while chapter five outlines the conclusion and recommendation

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Soil quality

According to Doran *et al* (1996), soil quality is defined as the capacity of the soil to function in an ecosystem and land use boundaries to sustain biological productivity, maintain environmental quality and promote plants and animals' health. It can also be defined as the capacity of the soil to ensure environmental sustainability of the soil, through physical, chemical and biological properties which are responsive to functional changes in the soil (Aparicio and Costa, 2007; Obade and La, 2016; Qi *et al.*, 2008). Soil quality can be defined in several ways depending on how the soil is used. It is impossible to measure soil quality directly. Indicators are rather used to measure soil quality. Soil quality indicators (SQIs) are the physical, chemical and biological characteristics of the soil that reflect the capacity of how the soil functions (Shukla *et al.*, 2006). It is difficult to comprehensively evaluate the conditions of soils with a single indicator because of their interdependency in determining soil quality (Guo *et al.*, 2018; Raiesi and Kabiri, 2016). Countless procedures for evaluating soil quality (SQ) have since evolved (Qi *et al.*, 2008). Because of the homogeneity and the complex system associated with soils, a general procedure in assessing soil quality becomes a challenge (Obade and La *et al.*, 2016). The integration of different properties gave birth to soil quality index (SQI) which becomes a reliable and a comprehensive tool for assessment of soil quality (Andrews and Carroll, 2001; Karlen *et al.*, 1998; Sanchez-Navarro *et al.*, 2015).

In forming a strong linkage between a number of soil properties, moderate labour and expenses in any soil data analysis, a Minimum Data Set (MDS) is considered as a way of choosing soil

indicators selection procedure which is greatly applicable in the calculation of soil quality (Andrews *et al.*, 2002; Liu *et al.*, 2014). Comparatively, a MDS procedure could select finest representative indicators with the reduction of excess data than Total Data Set (TDS) procedure (Nabiollahi *et al.*, 2017; Pang *et al.*, 2018). However, MDS techniques lack completeness in the data set of soil. It is necessary to establish if MDS procedure can sufficiently replicate TDS results for SQ evaluation.

## 2.2 Land degradation

Land degradation is caused by factors such as unsafe agricultural practices. Land-cover loss and lack of forest reservation are other drivers (Bewket and Stroosnijder, 2003, Eshetu *et al.*, 2004; Tsegaye *et al.*, 2010), insufficient land tenure security, over grazing and overstocking, lack of advantageous government policies, slash and burn and inadequate soil and water conservation policies (Eswaran *et al.*, 1997; Sanchez *et al.*, 2003; Tesfahunegn *et al.*, 2011). Land degradation is also caused by changes in inappropriate land use (Davaria *et al.*, 2020). Information has it that many dry farming lands were deserted as a result of degradation of soil quality (Davaria *et al.*, 2020). Forest lands are increasingly converted to farming lands to meet the demand for agricultural products due to the contemporary economic and population growth (Bakhshandeh *et al.*, 2019). Irresponsible use of these lands leads to soil erosion and degradation and destroys the natural ecosystem (Bruun *et al.*, 2013) and adversely affect soil health and its related properties (Saviozzi *et al.*, 2001; Raiesi and Beheshti, 2014; Davaria *et al.*, 2020). Organic matter can be added to soils that are degraded in order to recover its fertility status. Organic matter input is affected by land-use changes (Guo *et al.*, 2017) canopy structure (Finzi *et al.*, 1998), fertility of soil and water movement (Sakin, 2014; Six and Paustian, 2014) which change the intensity and the degree of

nutrient cycling and greatly affect productivity of soil. Physical degradation of land is influenced by soil surfacing, compaction and hardpans (Steiner, 1996). Bulk density increases with increasing compaction of soil due to surface loading leading to poor aeration, low hydraulic conductivity and causes injury to roots in penetrating the soil. Remarkably, in rainy seasons, light rainfall areas, hardpans are usually found in alluvial plains. Havoc in aggregates in the top soil causes crusting when raining is accompanied by soil erosion. Generally, crusting promotes water run-off and reduces water infiltration.

### **2.3 Chemical soil degradation**

It encompasses nutrients loss, acidification, increased soil salinity, loss of organic matter that breakdown the productivity of soil and indiscriminate application of pesticides. Many of the pesticides manufactured to boost agricultural production have become a killer of soil fertility. For example pesticides obstruct the chemical signals that allow micro-organisms (eg. *Azotobacter*) function in nutrient cycling reduce in population. With time, soils around pesticide treated plants become depleted in nitrogenous compounds and necessitates fertilizer application to increase yield and productivity of the soil (Fox *et al.*, 2007). Soil micro-organisms are responsible for the mineralization of both applied and native nutrient for the availability for plant uptake. Plants or crops (legumes) such as beans with root nodules harbour nitrogen fixing bacteria to alternatively convert atmospheric nitrogen into compounds such as ammonia, a useful compound (Kumar, 2015). Crop rotation is one of the appropriate agricultural practices employed as a remedy to recover soil productivity.

Soil acidification contributes to land degradation. Soil acidity is caused by dissolution of  $\text{CO}_2$  produced by decomposition of organic matter and root respiration in soil water as well as dissolution of atmospheric  $\text{CO}_2$  in rainwater to form carbonic acid in the soil. Also, reaction of  $\text{Al}^{3+}$  with  $\text{H}_2\text{O}$ , nitrification from ammonium from fertilizers and organic mineralization, acid rain and sulphur compounds in the soil. These give rise to pH changes which affect the physical, chemical and biological soil properties and processes and plant growth. Growth, yield and nutrition reduce as the soil pH reduces and increase as the pH increases to optimum. Ca, Mg, K, Na, Mb, B and nitrate–nitrogen are deficient in acidic soils whilst Al, Zn, Mn, Fe, Cu etc are prevalent. In soils with low pH, bacteria population and their biological activities are lowered while fungi are adapted to wide pH range. Electrical conductivity affects crop yield, nutrient and soil microbial activity. It affects crop yield in that the plant cannot extract sufficient water from the salt-affected soil because it is toxic to plants.

#### **2.4 Biological soil degradation**

It is linked to organic matter deficiency in the soil and vegetation cover. It is an indication of lower number of useful microbes and fauna in the soil environment. Biological soil degradation is a direct reflection of unsustainable soil management practices such as pesticides application, bushfire and adverse weather conditions. Physical structures of soils are affected and improved by soil organisms and organic matter content with respect to the mixing of organic matter and mineral substances, pore space in soil and transportation in the soil.

## 2.5 Indicators of Soil Quality

They are the physical, chemical and biological properties, processes and characteristics associated with soils that can be measured to monitor how the functions of soils change (USDA 1996). The ultimate useful indicators are dependent on what the soil is used for based on which its quality is evaluated. For instance, soils set as physical, chemical and biological settings for living organisms, filtering, transportation of water, buffering capacity, provision of mechanical support, immobilization and detoxification of organic and inorganic materials, storage and cycling of nutrients, provision of biological activity and diversity of plants and animals productivity.

It is demanding to segregate the role of soil into the aspects of physical, chemical and biological processes due to their linkages and dynamism in the soil system (Schoenholtz *et al.*,2000). Most soil quality parameters are interdependent in that one parameter result depends on another, Arshad and Martin (2002). There are four categories of Soil quality indicators namely visual, physical, chemical and biological categories.

### 2.5.1 Importance of soil quality indicators

Soil quality indicators play a vital role in relating their measurements to other resources, determining the health trend of a nation's soil, the collection of necessary information to determine trends, evaluating soil management practices and techniques as well as focusing on conservation efforts to maintain and improve soil conditions and giving guidance to land management decision making (USDA, 1996).

Observation and measurement of many different processes or properties in soils aid the estimation of soil quality. The measurement of one indicator depends on the other and that they are interdependent. Soil indicator selection is based on how land is used, the linkage between an indicator and the function of the soil to be assessed, variation between sampling times, the ease and reliability of the measurement, the required technique and interpretation of results and how sensitive the measurement is in managing the soil. These indicators can be categorized into physical, chemical and biological indicators.

## 2.6 Physical Indicators

According to Topp *et al* (1997), the strength and fluid transmission as well as storage properties in the rhizosphere of crops are attributed basically to physical qualities of agricultural soils. Soils with good physical qualities are fit enough for maintenance of a good soil structural system to resist erosion and compaction and hold crops firmly, but must be sufficiently feeble to permit root growth to proliferate soil fauna and flora. Good physical qualities of soil lead to fluid transmission and reservation properties that allow the right quantities of water and nutrients (dissolved) and proper aeration for optimum performance of crops with a reduced environmental degradation (Topp *et al.*, 1997). Marathon field-crop production is a recipe for a decline in physical qualities of agricultural soil. Poor crop performance and negative environmental impacts linked to off-field movement of soil and agrochemicals are a reflection of a reduction in the physical qualities of agricultural soil (Wallace, A., Terry, 1998). According to Wallace and Terry (1998), practical development of fresh strategies for maintenance and improvement on physical qualities of intensive land use for growing crops becomes herculean and snail pace as a result of compound

linkages including types of crops, tillage activities, texture of soil and average weather conditions. The optimum values for topmost crop yield whilst minimizing degradation of the environment for soil physical quality parameters remains a mystery (Wallace and Terry, 1998; Schipper and Sparling, 2000), though a number of practical guidelines of the physical parameters have been put forward for plant growth and improvement in both farming and non-farming soils. Adequate soil aeration and water conservation abilities coupled with appropriate strength of soil promote root growth and function. Solid particles arrangement and pores in soil are related to soil physical indicators. Depth of topsoil, water holding capacity, bulk density, and the ability to withstand external forces, texture, surfacing and how soil particles are closely packed or loosed are examples of soil physical indicators. They are basically a reflection of limitation to growth of plants roots, emergence of seedlings and movement of water and nutrients in the soil.

### **2.6.1 Soil particle size**

Texture of soil is the relative compositions of sand, silt and clay and how they are felt (Joint FAO/WHO Expert Committee on Food Additives., 2006). The separate particle size distribution of soil is classified into sand, silt and clay. Texture of soil is a primary property that affects soil productivity and plant growth. It influences how soil behaves in diverse ways. It is necessary for water reservation and usage, soil composition, aeration, mode of draining and soil's ability to function within the ecosystem. It also supports soil ecosystem and nutrient retention and distribution. This accounts for why soil texture measurement is necessary in the field of agriculture. The particles of sand are the largest whilst clay particles are the smallest. Most soil composites comprise all the three categories of soil particles. The comparative percentage of sand,

silt and clay describes the textural class of soils. According to Soil Science Society of America, Sand: 2.0-0.05 mm, Silt: 0.05-0.002 mm and Clay: <0.002 mm. Generally, there are twelve textural classes of soils as represented in the figure below.

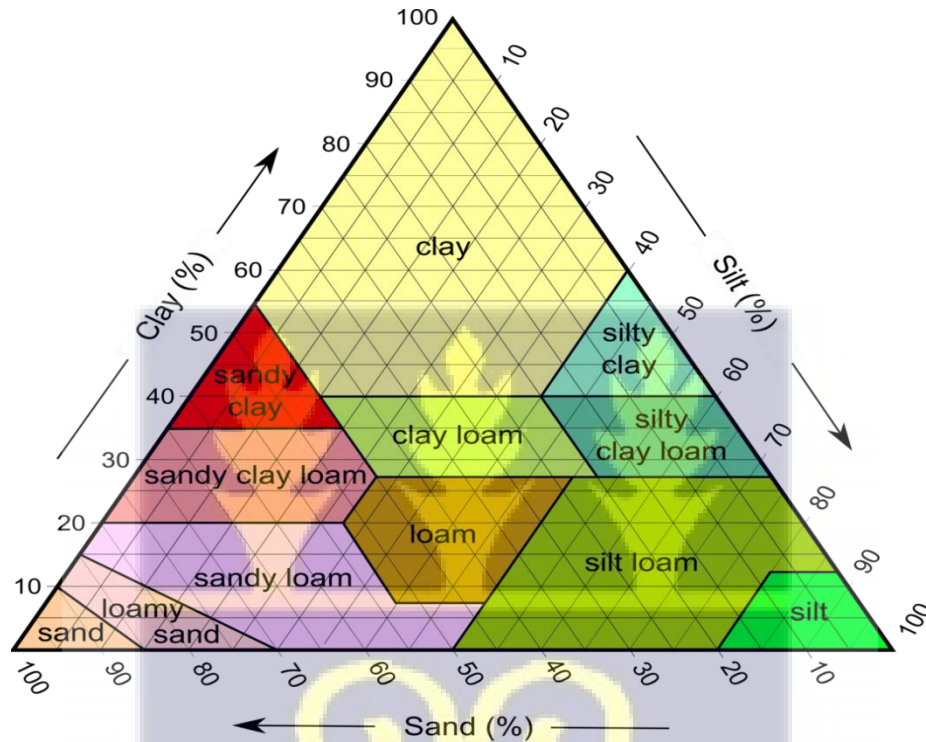


Figure 1: Soil texture triangle Source: Thinkingcountry.com

### 2.6.2 Soil moisture content

This is a critical parameter that regulates several hydrological, terrestrial as well as biogeochemical processes (Su & Shangguan, 2019; Yang *et al.*, 2012). It concerns water distribution and circulation, topographic processes, dissolution and cycling of chemical elements and compounds between life giving and nonlife giving components of the ecosystem (Su & Shangguan, 2019;

Yang *et al.*, 2012). In dry and degraded ecosystem, moisture content plays a key role in the determination of ecosystem compositions and functions (Fu *et al.*, 2016; Yan *et al.*, 2015). It determines plants yield and health directly. It also constitute most of the plants water conducted through roots and reflects plants water condition (Jin *et al.*, 2016; Mi *et al.*, 2016; Saf and Ünlükara, 2013). Soil moisture above or below certain limits inhibits plants growth and performance. It always supports the life of microbes and how they function and also serves as a sink to pesticides. The transformation rate of pesticides in soils requires appropriate moisture content to achieve that purpose. There is another section of soil water that binds soil particles. The negative and positive charges that represent the chemical properties of water are the reasons for the film of water around soil particles. Surface moisture retention is as a result of surface retention and surface attraction forces for colloidal water retention. Soil moisture and pH are the main determinants of reaction in the soil. Soil moisture regulates temperature and gaseous exchange, dissolved nutrients in the form of salts as well as satisfaction of water demands for plants. Soil moisture gives Information on crop yield and water holding capacity of soil, schedule for irrigation, and the extent of biological and chemical activities in the soil, water content and rate of its movement in the soil.

## **2.7 Chemical indicators**

Chemical indicators of soil quality include soil pH, electrical conductivity (EC), available phosphorus, nitrogen, potassium, soil organic matter and carbon Doran and Parkin (1994). In other perspectives, it includes soil pH, phosphorus concentration, organic matter, soil salinity, cation exchange capacity, concentration and cycling of heavy metals and radioactive substances which are potential contaminants or other essential elements required for plants growth and development

(USDA, 1996). Sixteen nutrients are usually grouped into micro and macronutrients which are very important for plants and animals' growth and development. Macronutrients describe plants nutrients for development that are required in high quantities such as Hydrogen, Carbon, Nitrogen, Oxygen, Magnesium, Phosphorus, Sulphur, Potassium and Calcium whilst micronutrients are crucial for plants development and growth but are required in minute amounts such as Chlorine (Cl), Boron (B), Manganese (Mn), Copper, Iron (Fe), Molybdenum (Mo) and Zinc (Zn) Roy *et al* (2006). Soil pH gives a clue on which elements are present in soil and their toxic levels (Thomas, 1996). Most chemical reactions have effects on nutrient availability due to pH levels that influence soil chemical environment (Schoenholtz et al., 2000).

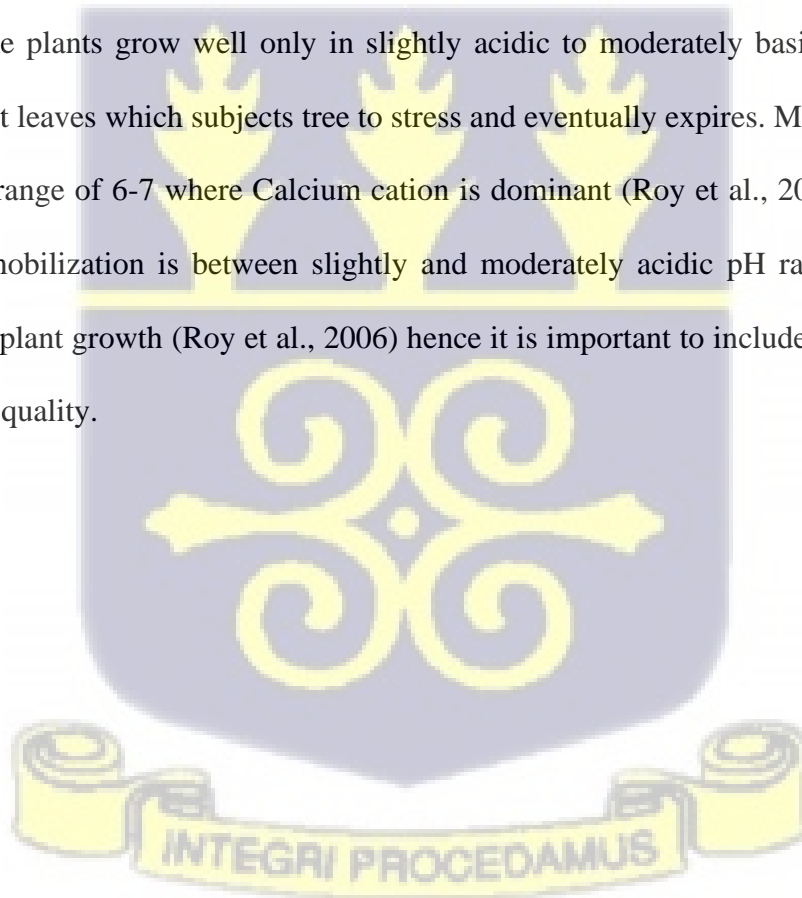
The pH of soils near neutral values, contain a lot of available nutrient (Boggs 2016). The chemical nature of soil affects soil and water quality, buffering capacities, nutrients availability and other organisms, transportation of contaminants and soil surfacing. Assessment of soil quality is dependent on specific function of the soil (Larson and Pierce, 1994). Chemical indicators are largely used to measure basic functions of soil such as productivity and biodiversity activity, filtering, degrading, buffering, removal of toxins from organic and inorganic materials, regulation and partition of water and solute flow, nutrient and carbon cycling, provision of physical stability of organisms as well as structures that support human habitation. Soil chemical unit and characteristics affect several reactions and activities that go on in the soil environment. Example, soil pH regulates the solubility and movement of Al, Fe, Mn, Cu and Zn (heavy metals) and phosphorus as nutrients. Also, pH controls many heavy metals toxicity and affects percentage saturation, the buffering capacity of the soil, CEC, microbial growth and diversity with the exception of acidophil organisms which are highly sensitive to low pH conditions of soil compared to fungi.

Soil physical and biological indicators like chemical indicators, are sensitive to soil management practices and natural interferences. Practices such as tillage (e.g, continuous till, conservation till, and organic and inorganic amendments) can possibly alter pH, total organic carbon (TOC), phosphorus and nitrate levels in soil. If soil pH is not corrected by practices such as liming, soil acidification would occur. Continuous administration of elemental sulphur (S), ammonium nitrate  $(\text{NH}_4)_2\text{NO}_3$  and ammonium sulfate  $(\text{NH}_4)_2\text{SO}_4$  to basic soils reduces the pH levels of the soil. Soil salinity is as a result of higher concentrations of salt in irrigation water hence will have high EC values. Other soil chemical properties such as percent base saturation and exchangeable sodium percent (ESP) have been proposed as possible indicators of soil quality.

### 2.7.1 Soil pH

It is a vital determinant of fertility status of soil as it influences the solubility of metal ions for example Aluminum, Manganese, copper, Zinc, Iron and Molybdenum. It affects the supply of cations and anions as soil nutrients and influences microbial lives and activity in soils. Acidic soils lack phosphorus and base cations such as Mg, Ca and K (Heil and Sposito 1997). It is a primary property with vital influence on soil physical, chemical, and biological processes hence it is considered as a pivotal soil parameter (Liu et al., 2013; Ávila et al., 2017). Acidification of soil can lessen availability of some nutrients in the soil (Liu et al., 2013). In the same way also, it increases the availability of the concentrations of some heavy metals to toxic levels capable of contaminating agricultural products and renders the soil infertile (C. Li et al., 2014). Acidification of soil occurs over a long period of geographical (hundreds to millions) years as it is naturally a slow phenomenon (Guo et al., 2010). It is considered a master soil quality that influences many physical, chemical and biological properties and activities and also affects plant growth and

biomass yield. Low pH levels reduce bacterial population and processes whilst fungi survive a wide pH range. At low pH levels, organic matter mineralization is reduced or halted due to poor microbial processes and inhibits nitrification and nitrogen fixation. Pesticides movement and degradation and heavy metals solubility depend solely on pH. Out of the sixteen essential nutrients of plants, fourteen are obtained from the soil. Nutrients that are used by plants must be in solution form. Greater number of minerals and nutrients are soluble or available in soils with low pH to a larger extent than in neutral or slightly basic soils. Soil with pH of 4.0-5.0 (extremely and strongly acidic soils) becomes highly possible to contain high levels of Al, Mn and Fe dissolved in it and becomes toxic to some plants for growth. Most plant nutrients are available at approximately 6-7 pH ranges. Some plants grow well only in slightly acidic to moderately basic soils leading to chlorosis of plant leaves which subjects tree to stress and eventually expires. Many plants survive in soil with pH range of 6-7 where Calcium cation is dominant (Roy et al., 2006). On the other hand, nutrient mobilization is between slightly and moderately acidic pH ranges which gives special edge for plant growth (Roy et al., 2006) hence it is important to include pH measurement in assessing soil quality.



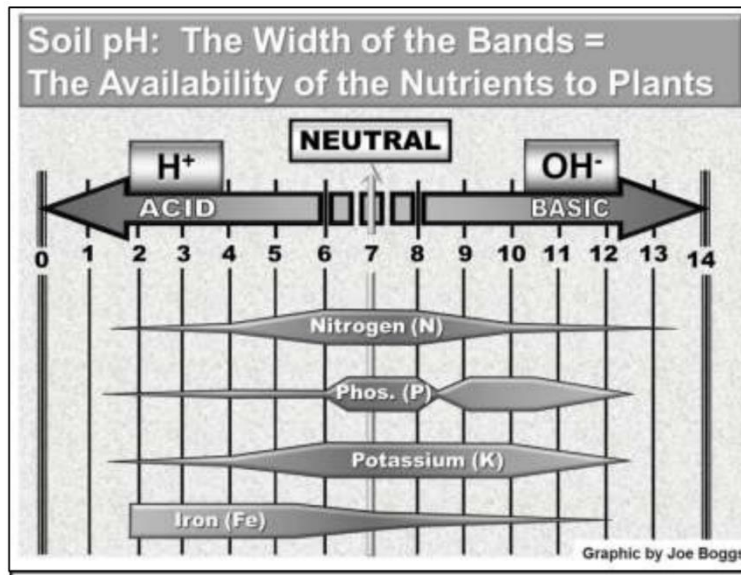


Figure 2: pH ranges for soil nutrients Source: (Boggs, 2016)

### 2.7.2 Changes in soil pH

Soil's acidity is caused by the deficiency of Mg, Ca, K and Na via leaching by rainwater, with dissolved CO<sub>2</sub>. The practice of liming soil ends up increasing its pH. Liming replaces hydrogen ions and eliminates the main challenges relating to acidity of soils as well as provision of Ca and Mg as nutrients. Liming also makes phosphorus more available for plant use and gives rise to availability of nitrogen by facilitating organic matter decomposition.

### 2.7.3 Cation exchange capacity

It is the capacity of a soil to supply cationic nutrients in soil solution for plants uptake or it is the number of exchangeable sites for cations of a soil. It supplies buffering effect to pH variations,

systemic changes and available nutrients and calcium levels to soil; hence it is the main agent that controls soil structural stability, availability of nutrients to plants for growth.

Soils with low CEC possess low resistance to soil chemistry variation due to land use and management applications. Its unit of measurement is centimoles of positive charge per kg soil. It is normally measured by displacing Na, K, Mg and Ca ions with other cations that are strongly adsorbed onto soil particles and the estimation of how strongly the adsorbed cations are held on to the soil particles.  $\text{NH}_4\text{Cl}$ ,  $\text{NH}_4\text{CH}_3\text{CO}_2$ ,  $\text{BaCl}_2$ ,  $\text{KCl}$  and  $\text{SC}(\text{NH}_2)_2$  are some of the well-known reagents that supply these strongly adsorbed cations. Table 2.1 provides standard CEC gradings.

**Table 2. 1:** Standard CEC grading

Grading	Very low	Low	Moderate	High	Very high
CEC(cmol(+)/kg soil)	Less than 6	from 6 to 12	from 12 to 25	from 25 to 40	Greater than 40
Metson (1961)					

#### 2.7.4 Exchangeable bases

$\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{Na}^+$  and  $\text{Al}^{3+}$  are the familiar cations found in soils where  $\text{Al}^{3+}$  is found in strongly acidic soils. Normally, manganese ( $\text{Mn}^{2+}$ ), copper ( $\text{Cu}^{2+}$ ), zinc ( $\text{Zn}^{2+}$ ) and Iron ( $\text{Fe}^{2+}$ ) are cations present in amounts whose contributions do not significantly complement the concentrations of cations in soils. It is a habitual exercise to determine the levels of only the five most abundant

cations ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{Na}^+$  and  $\text{Al}^{3+}$ ) but for the purpose of this analysis, the first four cations would be considered. Table 2.2 represents the standard ratings of exchangeable bases.

**Table 2. 2::** Standard rating for exchangeable bases

Cations	Very low	Low	Moderate	High	Very high
$\text{Ca}^{2+}$	0 – 2	2 – 5	5 – 10	10 – 20	>20
$\text{Mg}^{2+}$	0 - 0.3	0.3 -1.0	1 – 3	3 – 8	>8
$\text{K}^+$	0 - 0.2	0.2- 0.3	0.3 - 0.7	0.7 - 2.0	>2
$\text{Na}^+$	0 - 0.1	0.1- 0.3	0.3 - 0.7	0.7 - 2.0	>2

Source: Metson (1961)

Acidic and sandy soils tend to have low levels of exchangeable Ca and Mg through severe leaching and limit plants growth. In addition, potassium levels lower than 0.2 cmol(+)/kg is an indication of the possibility of plant to respond to potassium fertilizer when applied, especially in areas where there is a massive loss of potassium by grazing or harvesting (Abbott, 1989). For High concentrations of Na and Mg ions in soils make them more dispersive than soils with high concentrations in calcium and magnesium (Abbott 1989; Emerson and Bakker, 1973).

### 2.7.5 Organic matter

The component of the soil consisting of anything that once lived is called organic matter. Organic matter involves decomposed plant and animal reserves, cells and tissues of organisms in the soil, soil microbes and plant roots. A well putrefied plants and animals remains form humus. Humus is a spongy and porous dark brown material with earthy and pleasing odour. In the volume of most soils, organic matter composition is less than 5% (USDA, 1996). Organic matter in soils widely affect soil biodiversity which plays a basic key role in the ecosystem of soils (Busari et al., 2015). Microscopic arthropods which are highly susceptible to soil management practices that affect the environment of the soil (Aspetti et al., 2010) are involved in the decomposition of organic matter, nutrient cycling and stabilization of soil structure (Denef et al., 2001; Parisi et al., 2005; Chang et al., 2013). Plants do not obtain organic matter from the soil as nutrient but its cycling is necessary due to its linkage to nutrients in the soil (Nitrogen, Phosphorus and Sulphur) as well as its important contributions to soil physical, chemical and biological properties (Hoyle et al., 2011). As organic materials are degraded by microorganisms, nutrients may flee in plant available forms into the soil. The concentration of any element released in mineral form depends on the constitution of the degraded organic matter for example C : N, C : P and C : S ratios as well as the demand for population of microbes for any individual element in the soil (Heil and Sposito, 1997; White, 2010). Also, plants and animals remains in soils play a vital role in maintenance of soil structure and decreases the content of readily dispersible clay soil (Tisdall and OADES, 1982, Dexter, 2002).

Continuous use of land for cultivation destroys large aggregates of soil and its pores. Organic matter addition to soil means more food for consumption by surface feeding earthworms to create biopores for aeration and water infiltration (Oades, 1993), bacterial and fungal hyphae growth for

structural stability of soil due to excretion of mucilage of biopolymers and polysaccharides. Some standard soil parameter grading are shown in Table 2.3.

**Table 2. 3:** Some standard soil parameter grading

Parameter	Low	Moderate	High
Ca(cmol+)/Kg soil)	<5	5-10	>10
Mg(cmol+)/Kg soil)	<1	1-5	>5
K(cmol+)/Kg soil)	<0.5	0.5-1.0	>1.0
Na(cmol+)/Kg soil)	<0.3	0.3-1.0	>1.0
percent OC	<1.0	1.0-1.8	>3.0
percent OM	<0.9	0.9-1.7	>1.7
EC(dS /m)	0-1.1	1.2-4.4	>4.5

Source: Proffitt, 2014

Organic matter forms an important soil component since it serves as a energy and carbon sources for soil micro-organisms. It revamps upon the capacity of soil to retain and transfer air and water, enhances soil aggregate stability, reduces the risk of erosion, holds nutrients by supplying anion and cation exchange capacities. It lowers bulk density by maintaining soil in less compacted

forms, softens soil and makes soil less sticky, lessens adverse environmental effects of pesticides on soil organisms and holds carbon from the atmosphere and alternative sources.

### **2.7.6 Electrical conductivity of soil**

It is an electrolytic process that occurs chiefly via water-filled pores in the soil. The cations and anions from soil water containing dissolved salts convey and conduct electrical charges and electrical current respectively. Electrical conductivity (EC) depends on the levels of the ions present in the soil. Electrical conductivity mainly measures salinity of soil. It can however be used to estimate other soil properties in non-saline soil such as soil depth, moisture content and nutrient levels. It is usually measured in deciSiemens per meter (dS/m). For EC values of soil beyond 4 dS/m means they are estimated in their saturated extract form and are salty hence crops whose growths are saline sensitive are restricted in such soils. Recently sensors were employed for mapping EC and taking the concentration of nitrate. Smith and Doran (1996) gave an account of how nitrate increases with an increase in electrical conductivity of soil.

### **2.8 Biological indicators**

Soil microbes are beneficial components of soil and they perform a key role in crucial activities such as breakdown of organic matter, nutrient transformation, soil organic matter dynamics (Padhan et al., 2020) as well as control of nutrient availability in soil system through nutrients immobilization (Li and Han, 2016; Wang et al., 2019). Soil respiration and earthworm are often employed as biological indicators in comparative analysis to measure the effects of various

management practices of soil (D'Hose et al., 2014; Van Leeuwen et al., 2015) or keep track of how resilient a degraded soil is (Gil-Sotres et al., 2005). For that matter, biological properties of soil are the precise indicators of swing in quality of soil (Zornoza et al., 2015). Marathon fertilization had farther persistent effect on soil characteristics such as microbial diversity, biomass and activity (Hartmann et al., 2015). Biological properties give rapid response and are affected by management of nutrient and strong correlation to give report on biomass of microbes, soil respiration and enzyme activities (Frankeberger and Johanson, 1983; Li and Han, 2016). The Arbuscular mycorrhizal fungi performs a task in different soil processes chiefly cycling of carbon associated with protein binding influences and thrives via a spacial hyphal system that grows in soil wholly (Turgay et al., 2015); Parihar et al., 2020).

Measurements of the populations of soil macro and micro-organisms, their byproducts and activities are examples of biological soil quality indicator determinants. The rate of respiration can be used as a measure of microbial activity based on microbial decomposition of plants and animals remains present in soil. The fungal byproduct, ergosterol is considered as a measure of microbial activity and plays a key role in the formation of soil aggregate stability. The rate of breakdown of plant remains is dependent on microbial population and it is considered as soil biological indicator. In the food web, soil organisms feed on organic materials and themselves and it is the basis on which energy and nutrients keep exchanging and are made available to plants. Macro-organisms for instance earthworms and millipedes combine shredded dead leaves and its remains with the soil and make organic substances more available for immovable bacteria for use. Earthworms for example, can completely combine (mix) the highest six inches wet grassland soil for a decade or two whereas ants and termites mix soil materials and burrow arid and semiarid rangeland parts of soil.

Soil biota population is controlled by soil predators such as insects, beetles, spiders, ants (some not all), scorpions, centipedes and termites in the food web of soils. Also, springtails, nematodes, mites and single-cell protozoa as tiny soil organisms, feed on bacteria and fungi. Some soil organisms feed on crumbed remains, dead roots and the excrement of larger organisms. The main composition of soil biota comprises fungi and bacteria. Fungi and bacteria complete decomposition through degradation of the remaining soil materials and hoard energy and nutrients in the cells of their bodies. The leading organisms that attack rocks in the formation of new soils by liberating substances that decompose the rocks are algae and fungi.

### **2.8.1 Total microbial population**

The existence of enough nutrient and also enough number and diversity of soil microflora status of the soil are determined by fertility of soil. Soil microbial diversity is usually as a result of the occurrence of different particular kinds of organic substrates soil contains. The sets of different organisms that are mostly single-celled of prokaryotic or eukaryotic origination are bacteria, actinomycetes, cyanobacteria, algae and fungi. The above soil microbes perform different functions needed for befitting the roles soil performs in its dynamic system.

The population of microbes for every 1g of soil is an indication of a country's agricultural prosperity. The overall mass of microflora and fauna in soil is twenty times the population of living beings globally (Torsvik et al., 1990). For every 1g soil in good health, it harbours 1000000 to 100000000 bacteria responsible for OM decomposition, 0.15mg–0.5mg fungal hyphae, ten thousand to hundred thousand protozoa, a handful to many hundred microscopic arthropods, 15–

500 nematodes and a handful earthworms (Coleman, 1994). Soil bacteria and fungi decompose plants and animals remains that help to keep macroaggregates/clumps of soil particles.

Higher bacterial population occurs in soil but have diminutive biomass due to their tiny nature. Though the population of actinomycetes is 10 times lesser than that of bacteria, they possess not differing biomass compared to that of bacteria as a result of larger size they possess. Despite the fact that actinomycetes have heterogeneous groups that are grampositive, normally anaerobic bacteria are known for their thin and flexible threadlike and branching ontogenic form that leads to many compositions in expanded community or mycelium (Rao et al., 2005). In spite of smaller fungal population they constitute the highest soil biomass. Some soil microbes such as protozoa, bacteria and actinomycetes can survive soil turbulence compared to fungal population hence they are mostly represented in tilled soils whilst fungi and nematodes are the highest in untilled soils (Janušauskaite et al., 2013).

Analogous research by Torsvik et al (2002) indicated analogous account of microflora and fauna on the surface of soil horizon (Torsvik et al., 2002). Soil that surrounds and influences roots can constitute up to 10<sup>11</sup> cells of microorganisms for each gram of root and beyond 30000 prokaryotes mostly (Egamberdieva et al., 2008). This is an indication that organic substances have constructive link to microbial population. Organic matter rich soils are dominated by soil microflora and fauna compared to soil with low plants and animals remains. Soil microflora and fauna are dominant in forest soils (Mandal et al., 2013).



## CHAPTER THREE

### MATERIALS AND METHODS

#### 3.1 Study area

The study was conducted within the Asesewa in Upper Manya Krobo District in the Eastern region of Ghana and its surroundings. Majority of the people are farmers who mostly and annually rely on bushfire and ploughing for clearing their lands before growing of crops. The main crops grown are maize, beans and cassava whilst okro, garden egg and pepper are in minority. Ploughing, slashing, burning, application of fertilizer and pesticide application are inevitable farming practices amongst farmers in Asesewa.

The district is found in the eastern part of Ghana and was chosen for this study because agricultural production (farming) is pivotal in their economic lives. The crops are produced for local consumption and exportation. The District is located within latitude  $6^{\circ} 20''$  North and  $6^{\circ} 50''$  North and longitudes  $0^{\circ} 30''$  West and  $0^{\circ} 00''$  West. The land measures 885sq.km which makes up about 4.8% of the overall geographical area of the region. It shares boundaries with Volta lake due north and with sister districts such as Fanteakwa due west, Asuogyaman due east, YiloKrobo due south-west and Lower Manya Krobo due south-East. Upper Manya Krobo District (Asesewa being the capital) falls within semi-equatorial climate with two principal seasons being the moist (wet) and arid (dry) seasons. The wet season starts from the fourth month (April) of every year to the beginning of the eighth month (August) of every year whilst the arid season commences from the eighth to the tenth (October) months of every year. Normally, August is dry and cold whereas the eleventh month (November) to the third month (March) being dry and warm. The overall amount of rainfall amount is within 900mm and 1,150mm.

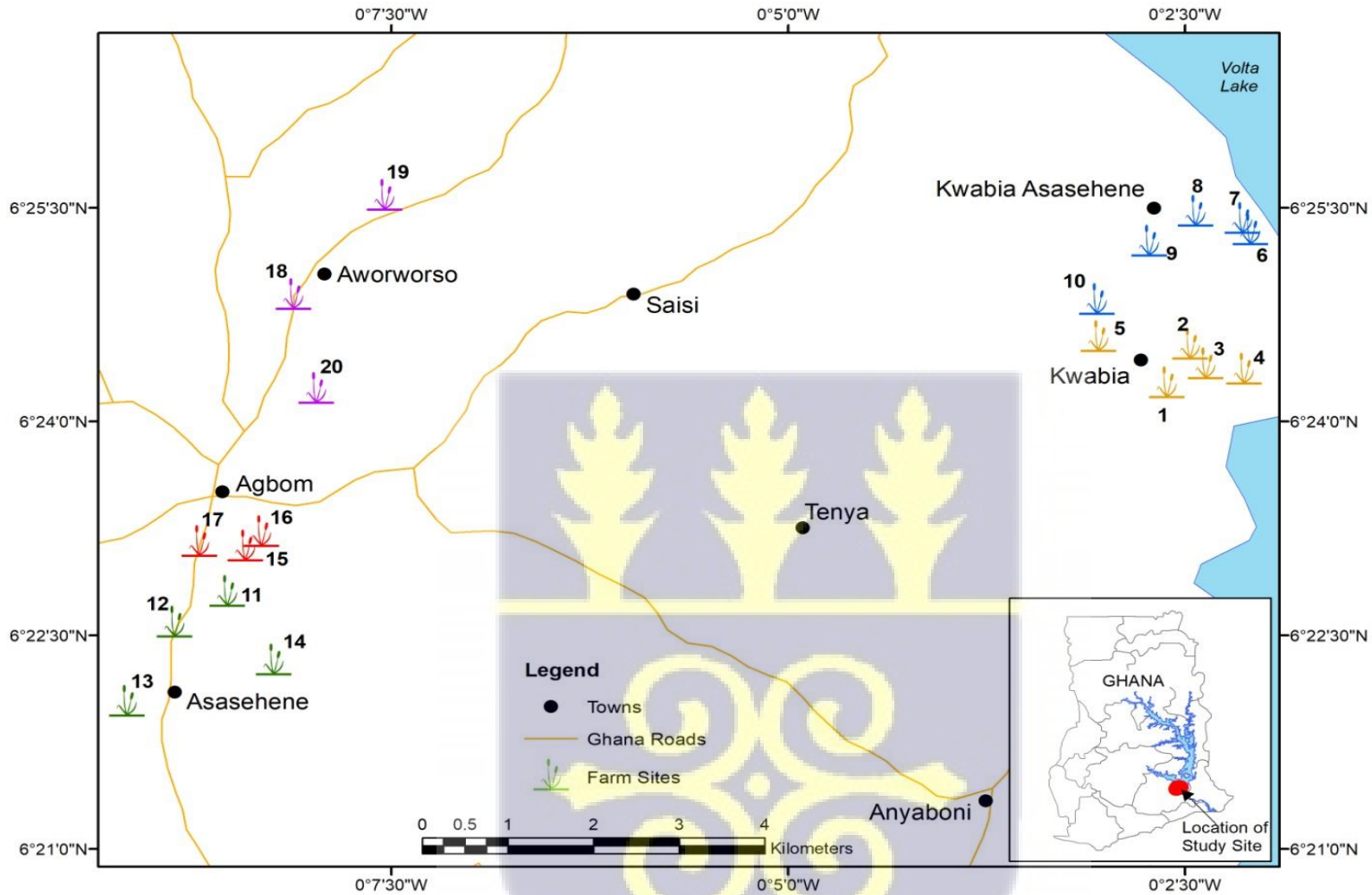


Figure 3: Map of study area making up the farming sites within Asesewa in the Upper Manya Krobo District and its surroundings.

### 3.2 Soil sampling

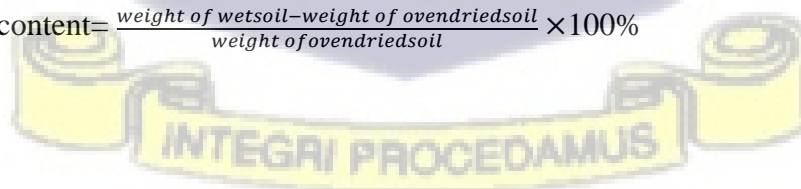
Soil samples were taken during October and November, 2020 from Kwabia (5 farms), Kwabia Asasehene (5 farms), Asasehene (4 farms), Agbom (3 farms) and Aworworso (3 farms) (Fig 3). Four representative soil samples were taken in each farm using plastic spoon at a depth of 0–15 cm. The samples were kept in plastic zip bags, labeled and placed in an ice chest containing ice and transferred to the lab where they were later homogenized to get accurate representative samples from each farm. In all, 80 samples were taken from twenty locations for the study.

### 3.2 Laboratory Analysis

#### 3.2.1 Moisture content analysis

50 g each wet soil sample was weighed into moisture cans and dried at 105 °C and oven dried for 24 hours. The hot sample was placed in desiccators and allowed to cool at room temperature and were reweighed. The percentage water content at field capacity of the samples was measured by the difference in mass between wet soil and oven-dried soil per oven dried soil expressed as a percentage. Mathematically,

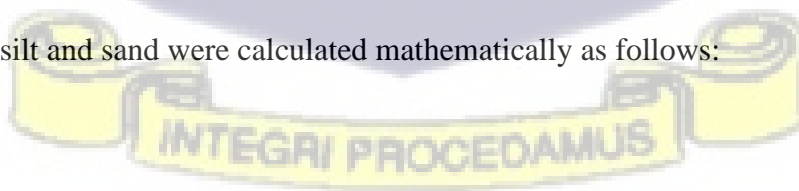
$$\% \text{ water content} = \frac{\text{weight of wet soil} - \text{weight of oven dried soil}}{\text{weight of oven dried soil}} \times 100\%$$



### 3.2.2 Particle size analysis

Bouyoucos (1962) method as modified by Day (1965) was employed for the measurement of particle size analysis for each of the twenty representative soil sample. 40 g each air dried homogeneous sample was weighed into dispersion bottles and pre-treated with 70% V/V hydrogen peroxide 1:1 (soil:solution) for the destruction of organic matter. 100 ml of 5 % calgon (sodium hexametaphosphate) solution had been added as a dispersion agent to form a suspension. These suspensions were shaken thoroughly on a mechanical shaker for two hours (2 hrs) in order to disperse each sample into sand, silt and clay. The suspensions were then transferred into 1 L sedimentation cylinder and topped up with distilled water to the mark.

Thereafter, a plunger was dipped into the suspensions in and out vigorously and left to stand. After five minutes a hydrometer was immersed and the first hydrometer reading was taken and recorded. The first density reading was for both silt and clay in the suspensions. The second hydrometer reading was taken and recorded after five hours (density of clay only in the suspension). The content of sand was determined by pouring the suspension directly onto a 47  $\mu\text{m}$  sieve. The content (sand) on the sieve was properly washed with tap water to wash off all clay and silt particles on the sieve and then transferred into moisture cans of known weights and dried in the oven at 105 °C for 24 hours and the weight of the oven dried sand was determined. Hydrometer readings in a blank that contains only 5% calgon were taken at five minutes and five hours' time intervals. The percentage clay, silt and sand were calculated mathematically as follows:



$$\%(\text{clay and silt}) = \frac{(5 \text{ minutes hydrometer reading})}{\text{mass of sample (g)}} \times 100$$

$$\% \text{Clay} = \frac{(5 \text{ hours hydrometer reading})}{\text{mass of sample (g)}} \times 100$$

$$\% \text{Silt} = \%(\text{clay and silt}) - \% \text{Clay}$$

$$\% \text{Sand} = \frac{(\text{oven dry weight of particles retained on the } 47 \mu\text{m sieve})}{\text{mass of sample (g)}} \times 100$$

The USDA textural triangle was used to determine the textural classes of the soil samples.

### 3.2.3 Soil pH measurement

The soil samples were air dried at 25 °C and sieved with less than 2 mm sieve. Soil pH was determined in distilled water of 1:1 mass to water ratio with a pH meter (ACCSEN, EL150 pH electrode). 20 g of each soil sample was weighed on an electronic balance into a beaker of 100 ml capacity followed by addition of 20 ml distilled water to form a soil-liquid suspension. It was then stirred for thirty minutes (30 mins) and was left undisturbed for a period of one hour to equilibrate. The pH meter was calibrated at buffers 4.01, 7 and 10.01 (triple point calibration). The pH of the soil samples were measured by immersing the probes gently into the suspension.

### 3.2.4 Measurement of electrical conductivity

The Soil samples were air dried at 25 °C and sieved with less than 2 mm sieve. The soil electrical conductivity was measured in distilled water of 1:5 mass to water ratio with the conductivity electrode using the pH meter (ACCSEN, EL150). Soil electrical conductivity was measured using

electrical conductivity probe. Ten (10 g) soil sample was weighed into 100 ml beaker followed by addition of 50 ml of distilled water to form soil-liquid suspension. The suspension was stirred for thirty minutes (30 mins) and left undisturbed for one hour to equilibrate. The conductivity meter was calibrated at buffers 1413  $\mu\text{s}/\text{cm}$ , 12.88  $\text{ms}/\text{cm}$  and 84  $\mu\text{s}/\text{cm}$  (triple point calibration). The electrical conductivity probe was gently immersed into the soil-liquid suspension to measure the electrical conductivity.

### 3.2.5 Extraction of exchangeable bases

5 g sample of the soil (fine) was weighed into a 200 ml extraction bottles for each sample. Fifty milliliters (50 ml) of 1 M  $\text{NH}_4\text{OAc}$  solution at pH 7 was transferred to the content of the extraction bottles. The bottles were covered tightly and shaken on a reciprocating mechanical shaker for 1 hr. The suspension was filtered with filter paper (Whatman No.42 filter paper). The filtrates were used to measure Ca, Mg, K and Na using Atomic Absorption Spectrophotometric techniques (AAS) (A Analyst 800). Appropriate standards were used for the calibration of the AAS device for calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) respectively to determine their absorbance. Concentrations of the basic cations in the filtrates were determined on the AAS device. Exchangeable bases were calculated as follow:

$$X(\text{cmol}_c\text{Kg}^{-1}) = \frac{R \times \text{volume of extract} \times 10^3 (\text{g}) \times 100 (\text{cmol}) \times E}{\text{Weight of soil} \times 10^6 (\mu\text{g}) \times M}$$

Where X = Basic cation,

R = Absorbance measured in  $\text{mgL}^{-1}$

E = Represents charge of cation

M= Basic cation's atomic mass

### 3.2.6 Cation exchange capacity (CEC)

5 g sample of the soil (fine) was weighed into a 200 ml extraction bottles. Fifty milliliters (50 ml) of 1M NH<sub>4</sub>OAc solution at pH 7 was transferred to the content of the extraction bottles. The bottles were covered tightly and shaken on a reciprocating mechanical shaker for 1hr. The suspension was filtered with filter paper (Whatman No.42 filter paper). After filtration, the residues were immediately leached four times with 50ml portions ethanol (in order to get rid of excess ammonium ion) into empty plastic bottles. The residues were again leached four times with 50 ml portions of acidified KCl (1 M). Each portion was added at a time and allowed to drain through the residue before adding the next portion. Ten milliliters (10 ml) of the leachates was transferred into a Kjeldahl flask and 10 ml solution of forty percent sodium hydroxide (40% NaOH) portions were added and distilled into 5 ml 2% boric acid. The solutions were back titrated against 0.01 M HCl solution. The ammonium ion concentrations in the various samples were determined as the CEC of the soil.

$$\text{CEC (cmol/kg soil)} = \frac{V(\text{HCl}) \times M(\text{HCl}) \times 0.001 \times \text{vol.of extract} \times 1000 \times 100}{\text{vol.of the aliquot} \times \text{weight of soil}}$$

### 3.2.7 Organic matter determination (Weight Loss-On-Ignition at 550°C)

50 g each of the wet soil sample was weighed into clean and well dried moisture cans. It was then dried in the oven for one day (24 hrs) at 105 °C. The hot sample was quickly placed in desiccator and allowed to cool at room temperature. Two grams (2 g) of each soil sample that was oven dried was measured into clean dry and already weighed heating crucible. The heating crucibles were arranged in a pattern that followed their labels and were placed in the VECSTAR muffle furnace at a temperature 550 °C for four hours. Thereafter, samples were allowed to cool and placed into

the desiccators to further induce cooling without absorbing moisture and the contents reweighed to determine weight loss after ignition.

Percent organic matter is calculated as follows:

$$\% \text{ Organic Matter} = \frac{\text{Weight of sample at } 105^{\circ}\text{C} - \text{Weight of sample at } 550^{\circ}\text{C}}{\text{Weight of sample at } 105^{\circ}\text{C}} \times 100$$

### 3.2.8 Biological Analysis

**3.2.8.1 Preparation of Ringer's solution:** 2.15 g sodium chloride (NaCl), 0.075 g potassium chloride (KCl), 0.12 g calcium chloride (CaCl<sub>2</sub>) and 0.5 g hydrated sodium thiosulphate (Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>·5H<sub>2</sub>O) were weighed and dissolved in distilled and topped up to the 1 L mark.

**3.2.8.2 Preparation of nutrient agar solution:** 28 g of nutrient agar was dissolved in distilled water and made up to the 1 L mark and autoclaved at 121 °C for 15 minutes.

#### 3.2.8.3 Method:

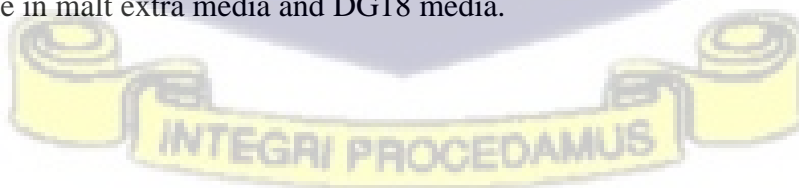
10 g sample of fine soil was transferred into ninety milliliters (90 ml) sterilized Ringer's solution followed by shaking in sterilized medicinal bottle. Using aseptic technique, the cap of the test tube was removed from the 9 ml dilution blank (Ringer's solution) and the mouth was flamed. 100 microlitres (100 µL) of the suspension was pipetted into 9 ml Ringer's solution (blank) in a screw cap test tube with sterile micropipette for each subsequent transfer. Using aseptic technique, 1 ml of the diluents from the 10 to the negative 1 dilution was transferred to the 10 to the negative 2

dilution blank which followed in that order to 10 to the negative 5 dilution blank ( serial dilution of  $10^{-1}$ ,  $10^{-2}$ ,  $10^{-3}$ ,  $10^{-4}$  and  $10^{-5}$  ) and recapped and shaken for about 1 min in each case. The micropipette tips were changed in each case. 100  $\mu$ l of serial diluents  $10^{-4}$  and  $10^{-5}$  (duplicate of each) were pipetted into a sterile petri dish followed by pouring 12ml to 15ml of melted nutrient agar (pour plate method) solution. It was then covered and gently shaken and allowed to set. The petri dish and its content was placed in the incubator at 37 °C for 3 days when growth was observed. The number of microorganisms was estimated using marker on the Colony Forming Units (CFU). Plates with too numerous colony forming units to count (TNTC above 300) and plates with colony forming units too few to count (TFTC below 30) were ignored. The number of microorganism was estimated as follows:

$$\text{Microbial population} = \frac{\text{CFU}}{\text{Dilution factor per gram of sample}}$$

#### 3.2.8.4 Fungal population for ten farms (Kwabia and Kwabia Asasehene)

The four soil samples each from the eleven farms were homogenized. Ten (10 g  $\pm$  0.1 g ) of each was analyzed in the Department of Botany for soil mycoflora profile and population analysis. The analysis was done in malt extra media and DG18 media.



### 3.3 Media formulation and Preparations

#### 3.3.1 Formulation and preparation of malt extract agar (Oxoid CM167)

**Table 3. 1:** Materials and their quantities for preparing malt extract agar

Material	Quantity
Malt extract	30.0g
Mycological Peptone	5.0g
Agar	15.0g
Distiled Water	1000mL
Ph	5.4±0.2
Temperature	25°C

#### 3.3.2 Formulation and Preparation of Dichloran-glycerol (DG18) Agar (Oxoid CM167)

**Table 3. 2:** Materials and their quantities used in the preparation of Dichloran-glycerol (DG18) Agar (Oxoid CM167).

Material	Quantity
Peptone	5.0g
Glucose	10.0g
Potassium dihydrogen phosphate	1.0g
Magnesium Sulphate	0.5g
Dichloran	0.002g
Agar	15g
pH	5.6±0.2
Temperature	25°C

### **3.3.3 Preparation of malt extract agar (MEA) and Dichloran-Glycerol (DG18) agar**

50 g of MEA or 31.8 g of DG-18 powder were weighed and dissolved in 1L distilled water after which the mixture was heated in a water bath for about 10 minutes for complete dissolution. The solution was transferred into medicinal bottles and was sterilized at 121 °C and 1.1 Kg/cm<sup>3</sup> pressure for 15 mins in an autoclave.

### **3.3.4 Preparation of peptone water**

1% peptone water was prepared by dissolving 1 g in 99 ml of distilled water. Exactly 10ml aliquots were dispensed into McCartney tubes and autoclaved at 121 °C (1.11kg/stem pressure) for 15 minutes. These were used for the various serial dilution preparations.

### **3.3.5 Isolation and identification of mycoflora population**

One percent (1%) peptone water was used for serial dilution preparations of a stock solution of 10 g sample/100 ml of peptone water of each sample into a McCartney tube filled with 9 ml of the aliquot (peptone water) and a serial dilution up to 1:10<sup>3</sup>. Each tube was shaken at 140 rev/min for 2-3 mins on an orbital shaker (Gallenkamp, England). Serial dilution up to 1:10<sup>3</sup> aliquot was made and 1 ml aliquot was plated on 20 ml of either MEA or DG18 and incubated at room temperature (26°C) for 7 days. Colonies of mycoflora appeared were counted and calculated as *log*<sub>10</sub> CFU/g sample. Fungi isolated were identified by their cultural, colour morphological characteristics (microscopic and macroscopic) according to Barnett HL (2006); Samson and Reenen-Hoekstra (1988); Von Arx (1970) as well as other relevant identification manuals.

### 3.4 Quality Control/ Quality Assurance

For the study, samples were carefully handled during sample collection, transporting, preparation, analysis to avoid any external influences that could interfere with the integrity of the sample and hence contaminate it; protocols were carefully followed for each analytical parameter alongside careful tracking of samples for error minimization. Also, results and data entry including reporting were carefully done to avoid statistical errors. To minimize chemical (photochemical and microbiological degradation) and physical (volatilization, adsorption, diffusion, and precipitation) changes between collection and analysis sample bags were well sealed and the cooler which contained samples with ice was airtight. Samples were kept in the refrigerator until all chemical and biological analyses were carried out. Extractions were carried out within one week after sampling. Quality assurance measures applied in the laboratory included rigorous contamination control procedures (strict washing and cleaning procedures), analysis of procedural blanks, monitoring of detector response and linearity. During extraction, blanks duplicates were included in the analysis and re-calibration standards run frequently to check the linearity of the determination. For validation of the analytical procedure, repeated analysis of the samples against internationally certified/standard reference material was used. Except for the temperature, multi-probe meters were calibrated together using the same standard and procedures. Electrical conductivity was calibrated against 0.005 M, 0.05 M, and 0.5 M standard potassium chloride solution; pH was calibrated with standard buffer at pH of 4, 7 and 10. The temperature was checked against standard mercury thermometer for consistency.

All reagents used during the analysis were of high quality and exposed to the same extraction procedures and subsequently run to check for interfering substances. Sample of each series was analyzed in duplicates.

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.0 General Overview

From the study, the soil quality parameters as determined for Asesewa (Upper Manya Krobo District) revealed that majority of the soils present in the area were depleted, made mostly of sandy soil texture which was not ideal for the agricultural produce from the area. Also, other chemical measurement conducted revealed that soils from the Kwabia Asasehene area were more depleted in terms of exchangeable cations while soil microbial population was also low, an indication of less fertility of the soil. When compared to the standard values for soil quality assessment, the soils within the Asesewa (Upper Manya Krobo District) were found to be between low to moderate qualities which is not desirable for intensive farming activities.

#### 4.1 Distribution of soils across the Sampling Area

The study soil samples were collected from 20 farms located in five towns within the Asasewa District, namely Kwabia, Kwabia Asasehene, Asasehene, Agbom and Aworworso. In all the majority of the samples were collected from both the Kwabia and Kwabia Asasehene areas while the least samples were collected from Agbom and Aworworso communities. The number of samples collected was dependent on the area size and the number of different farms present. Fig. 4 presents the distribution of samples across the study area.

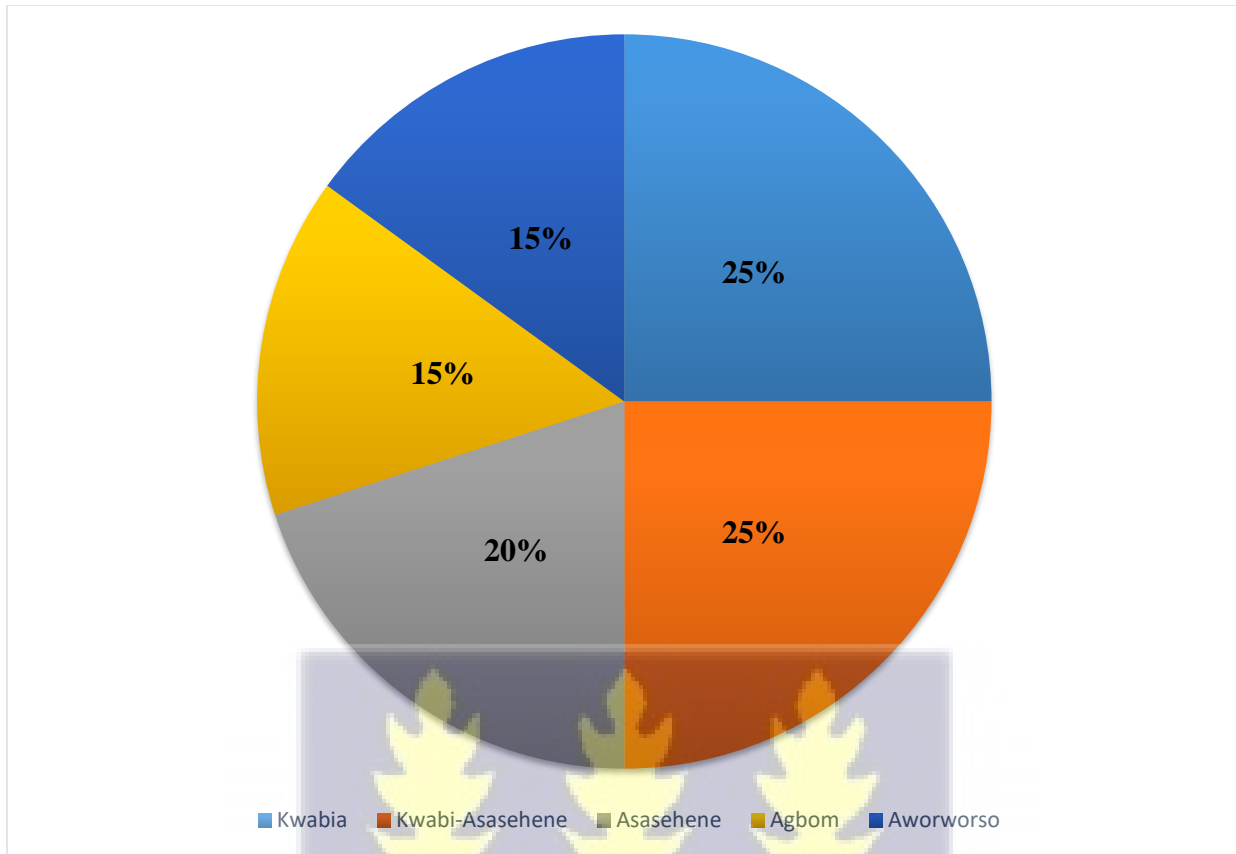


Figure 4: Distribution chart of samples from the towns in the study area

#### 4.2 Particle size and Percent moisture content

Soil texture is a physical property that provides information on the particle size of soils. It is an essential determinant of water accessibility and reservation, soil composition, water holding capacity, ability of soil to function for a particular purpose, aeration, nutrient transportation and reservation and soil biodiversity (Schoenholtz et al., 2000).

In the study conducted, it was observed that majority of the farms studied had sandy texture as the highest type of soil present. The mean compositions of the soils were 69.9% sand, 22.7% clay and

7.6% silt with the soil texture from the farms in Kwabia area more clayey texture compared to the rest (Table 4.1). Also, the percentage moisture content in the soils which is influenced by temperature, soil type and rainfall was within the range of 2.21% to 12.13% which confirmed the soil texture analyzed as sand soils are known to exhibit the poor water retention capacity.

**Table 4. 1:** Average values of Soil moisture content and particle Size distribution

S/N (Farms)	% moisture	% clay	% silt	% sand	textural class
<b>KWABIA</b>					
1	6.99	34.04	5.24	60.72	Sandy clay loam
2	6.54	32.63	19.03	48.34	Sandy clay loam
3	12.13	24.10	8.50	67.40	Sandy clay loam
4	7.48	44.20	13.80	42.00	Sandy clay loam
5	8.27	31.33	10.44	58.22	Sandy clay loam
<b>KWABIA ASASEHENE</b>					
6	6.27	19.40	3.90	76.80	Sandy loam
7	4.93	25.04	6.59	68.37	Sandy clay loam
8	2.21	21.93	7.74	70.33	Sandy clay loam
9	4.71	16.90	6.50	76.60	Sandy loam
10	2.46	15.60	5.20	79.30	Sandy loam
<b>ASASEHENE</b>					
11	8.53	18.20	5.20	76.60	Sandy loam
12	6.56	21.10	5.30	73.60	Sandy clay loam
13	7.39	21.00	5.20	73.80	Sandy clay loam
14	6.77	18.80	17.50	72.88	Sandy loam

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**AGBOM**

<b>15</b>	7.50	17.00	7.30	76.00	Sandy loam
<b>16</b>	7.53	19.80	3.70	76.20	Sandy clay loam
<b>17</b>	6.47	20.00	5.00	75.00	Sandy clay loam

---

**AWORWORSO**

<b>18</b>	4.47	19.60	4.90	75.5	Sandy loam
<b>19</b>	6.25	17.70	5.10	77.20	Sandy loam
<b>20</b>	5.35	17.40	7.50	75.10	Sandy loam

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**RSD= ± (0.3-1.5)%**

**4.3 Chemical properties**

**4.3.1 pH, Electrical Conductivity and Percent Organic Matter**

From the study, the pH, the electrical conductivity and organic matter content of the soil samples were analyzed to give information on the soil, as the pH and electrical conductivity will provide information on the key elements present in the soil which might be useful to the overall growth of plants. According to USDA Natural Resources Conservation Service (1998), a pH between slightly acidic and neutral (that is between 5.00-7.00) is considered ideal for soils for agriculture. From Table 4.2, the average pH observed for the study was 6.04 from a range of 4.88 to 7.26 for all the soil samples. This implies that the soil sample had optimum pH which was good for cultivation of crops.

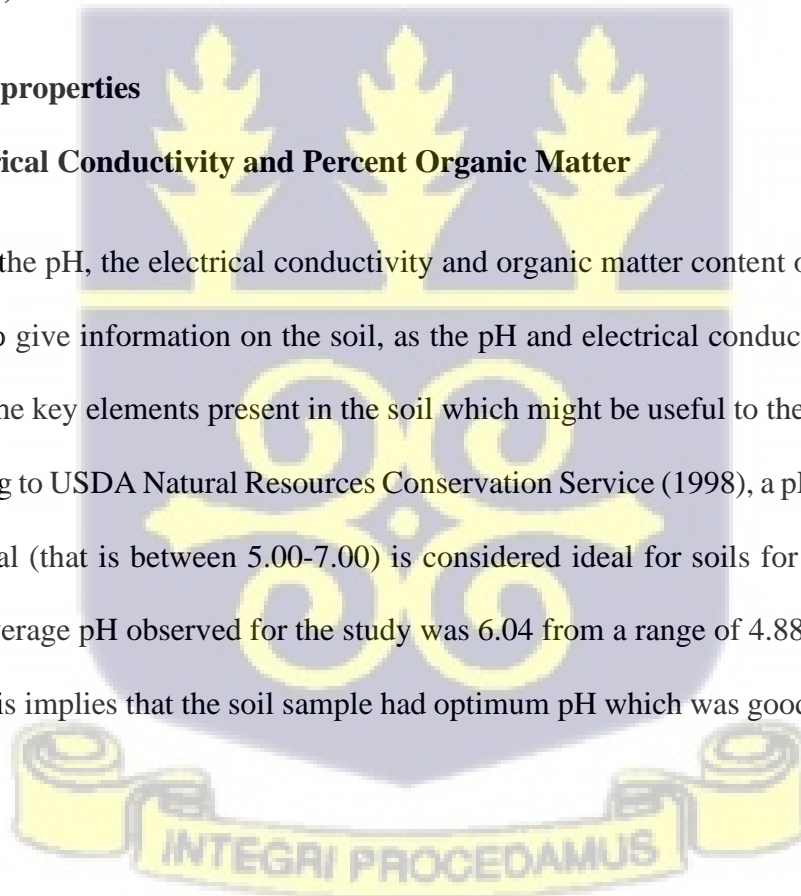


Table 4. 2: Mean values of Soil pH, electrical conductivity and percent organic matter.

S/N (Farms)	Ph	EC (dS/m)	% organic matter
<b>Standard Values</b>	6.5 <sup>a,b</sup>		3.5 <sup>a</sup>
<b>KWABIA</b>			
1	6.71	0.138	3.90
2	6.04	0.066	5.90
3	6.67	0.043	7.90
4	5.05	0.053	4.40
5	4.88	0.074	5.80
<b>KWABIA ASASEHENE</b>			
6	5.00	0.049	4.80
7	6.55	0.167	2.80
8	6.58	0.107	3.30
9	5.68	0.099	3.90
10	6.32	0.083	0.50
<b>ASASEHENE</b>			
11	5.79	0.045	3.90
12	5.48	0.052	2.90
13	7.25	0.136	3.00
14	7.26	0.128	2.70
<b>AGBOM</b>			
15	6.42	0.317	3.40
16	6.23	0.027	3.50
17	6.39	0.060	3.80

<b>AWORWORSO</b>			
<b>18</b>	5.47	0.077	3.00
<b>19</b>	5.19	0.059	3.90
<b>20</b>	5.83	0.060	4.40

<sup>a</sup>Karlen et al., 1994; <sup>b</sup>Rahman et al., 2017; **RSD = ± (0.3-1.5)%**

On the other hand, electrical conductivities for the soil were very low with values between 0.027 and 0.317 with an average EC of 0.101 dS/m (Table 4.2). This showed that the soil might have few elements present which may also signify that the soil had low nutrient content hence the possible decline in production. Also, the percentage organic matter content measured for the soil was high ranging from 0.5% to 7.90% (Table 4.2) which confirms the observation from the electrical conductivity hence requiring that activities to increase the organic content so as to boost agricultural production.

#### **4.3.2 Cation exchange capacity and exchangeable bases**

Cation exchange capacity is a parameter which assesses the number of exchangeable sites present in a sample for nutrient cations. A high exchange capacity is usually desirable as it confirms how rich the soil is rich in nutrients that might be required for plant growth. Also soils with low values will possess low resistance to variations in the soil chemistry and overall nutrient content which mostly arises from bad land management practices. From Table 4.3, it is observed that most of the soil samples analyzed averagely showed moderate cation exchange capacity with the exception of

Aworworso and Agbom that recorded high cation exchange capacity, except for soils from the Kwabia Asasehene which had very low values.

Cation exchange capacity values determined ranged from 10.77 – 33.31(cmol (+)/Kg) across all the soils. In terms of nutrient cations, the presence of Calcium was moderate for samples in Kwabia, Asasehene and Agbom whilst it was low in concentration for Aworworso and Kwabia Asasehene samples. In total, the cation exchange capacity was moderate, with the exception of Aworworso. Sodium and Magnesium cations were low compared to potassium ions which were higher. This indicates that the soils indeed were not rich in nutrients and the high Potassium content arising from the excessive fertilizers application the farmers had to apply so as to boost their production yields.

Table 4. 3: Exchangeable bases and cation exchange capacity

S/N (Farms)	CEC (cmol(+)/Kg soil)	Exchangeable bases (cmol/Kg)			
		Ca	Mg	K	Na
<b>Standard value</b>	20.00 <sup>a,b</sup>	-	-	-	-
<b>KWABIA</b>					
1	13.70	7.675	2.998	0.802	0.265
2	15.33	8.987	2.399	0.842	0.326
3	24.67	11.567	3.117	1.088	0.411
4	32.48	8.907	2.732	0.775	0.315
5	24.90	6.612	2.001	0.878	0.342
<b>KWABIA ASASEHENE</b>					
6	13.06	3.568	0.986	0.653	0.325
7	16.68	5.783	1.422	0.771	0.350
8	14.82	6.018	1.075	0.904	0.381
9	12.05	3.578	1.028	0.693	0.333
10	13.44	5.626	1.006	0.828	0.324

<b>ASASEHENE</b>					
<b>11</b>	10.77	3.488	0.779	0.727	0.347
<b>12</b>	15.20	3.993	1.019	0.634	0.344
<b>13</b>	29.18	9.885	2.288	0.890	0.342
<b>14</b>	23.11	7.385	1.266	1.273	0.504
<b>AGBOM</b>					
<b>15</b>	18.41	5.634	1.166	1.017	0.567
<b>16</b>	31.37	4.645	1.686	1.028	0.423
<b>17</b>	33.31	5.729	1.552	0.836	0.393
<b>AWORWORSO</b>					
<b>18</b>	31.85	3.492	0.901	0.700	0.368
<b>19</b>	32.87	3.527	0.965	0.698	0.336
<b>20</b>	24.13	3.213	0.692	0.628	0.342

<sup>a</sup>Karlen et al., 1994; <sup>b</sup>Rahman et al., 2017; **RSD= ± (0.5-1.7)%**

#### 4.4 Soil Microbial Population

In the determination of soil fertility, microbial population is one key factor which influences the rate of decomposition occurring in the soil to release nutrients into the soil for plants uptake. Hence a soil with high populations of microflora and fauna is usually identified as a life giving soil. For every 1g soil in good health, the soil harbors 1000000 to 100000000 bacteria responsible for OM decomposition, 0.15mg–0.5mg fungal hyphae, ten thousand to hundred thousand protozoa, a handful to many hundred microscopic arthropods, 15–500 nematodes and a handful earthworms (Coleman, 1994). From the study, the total microbial populations (for bacteria from table 4.4 and fungi) across all the farms were (insufficient for organic matter decomposition to influence soil fertility) too few to count (TFTC) except for two farms where the population was appreciable. Examples of common microbes (fungi) that were identified across the farms were *Streptomyces sp*, *Aspergillus fumigatus* and *Saccharomyces cerevisiae* etc (Fig. 5 and 6). The scarcity of microbial population reveals that the soils are far from been fertile.

Table 4. 4: Mean total microbial (bacterial) population with serial dilutions of  $10^{-4}$  and  $10^{-5}$

S/N	$10^{-4}$ CFU/g soil	$10^{-5}$ CFU/g soil
<b>KWABIA</b>		
1	$4.2 \times 10^5$	TFTC
2	$4.4 \times 10^5$	TFTC
3	$8.9 \times 10^5$	$4.3 \times 10^6$
4	TFTC	TFTC
5	$3.6 \times 10^5$	TFTC
<b>KWABIA ASASEHENE</b>		
6	$3.7 \times 10^5$	TFTC
7	$6.9 \times 10^5$	TFTC
8	TFTC	TFTC
9	$5.1 \times 10^5$	TFTC
10	$5.0 \times 10^5$	TFTC
<b>ASASEHENE</b>		
11	$3.3 \times 10^5$	TFTC
12	$4.9 \times 10^5$	TFTC
13	$9.5 \times 10^5$	$3.1 \times 10^6$
14	$7.0 \times 10^5$	TFTC
<b>AGBOM</b>		
15	$13.1 \times 10^5$	TFTC
16	TFTC	TFTC
17	$5.2 \times 10^5$	TFTC
<b>AWORWORSO</b>		
18	$6.2 \times 10^5$	TFTC
19	TFTC	TFTC
20	$4.0 \times 10^5$	TFTC

RSD=  $\pm$  (0.1-1.2)%

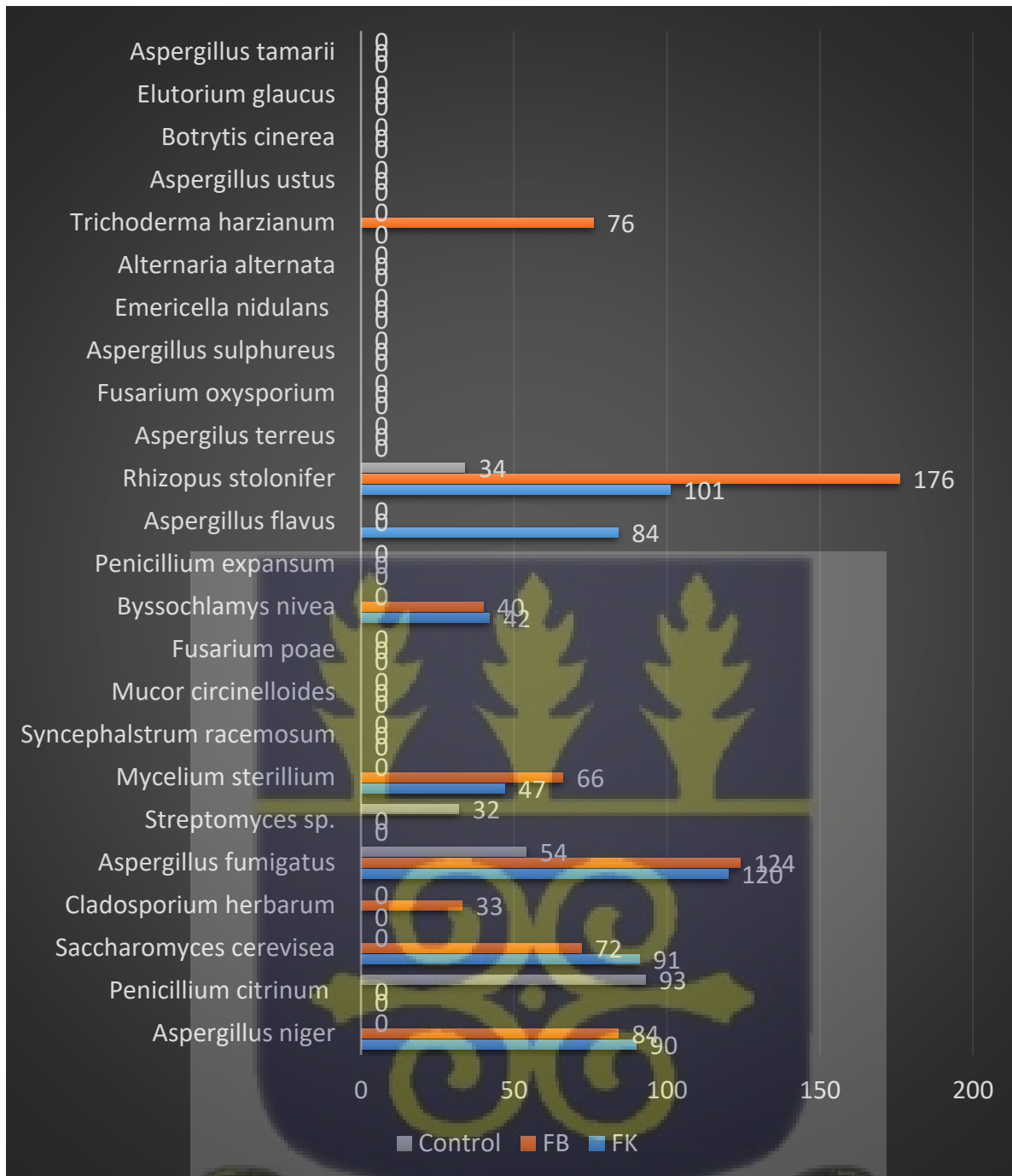


Figure 5: Soil mycoflora of farms in Asesewa in malt extract agar (MEA for fungi). Interpretation of keys: FB- Farms from Kwabia Asasehene, FK-Farms from Kwabia and C- Control

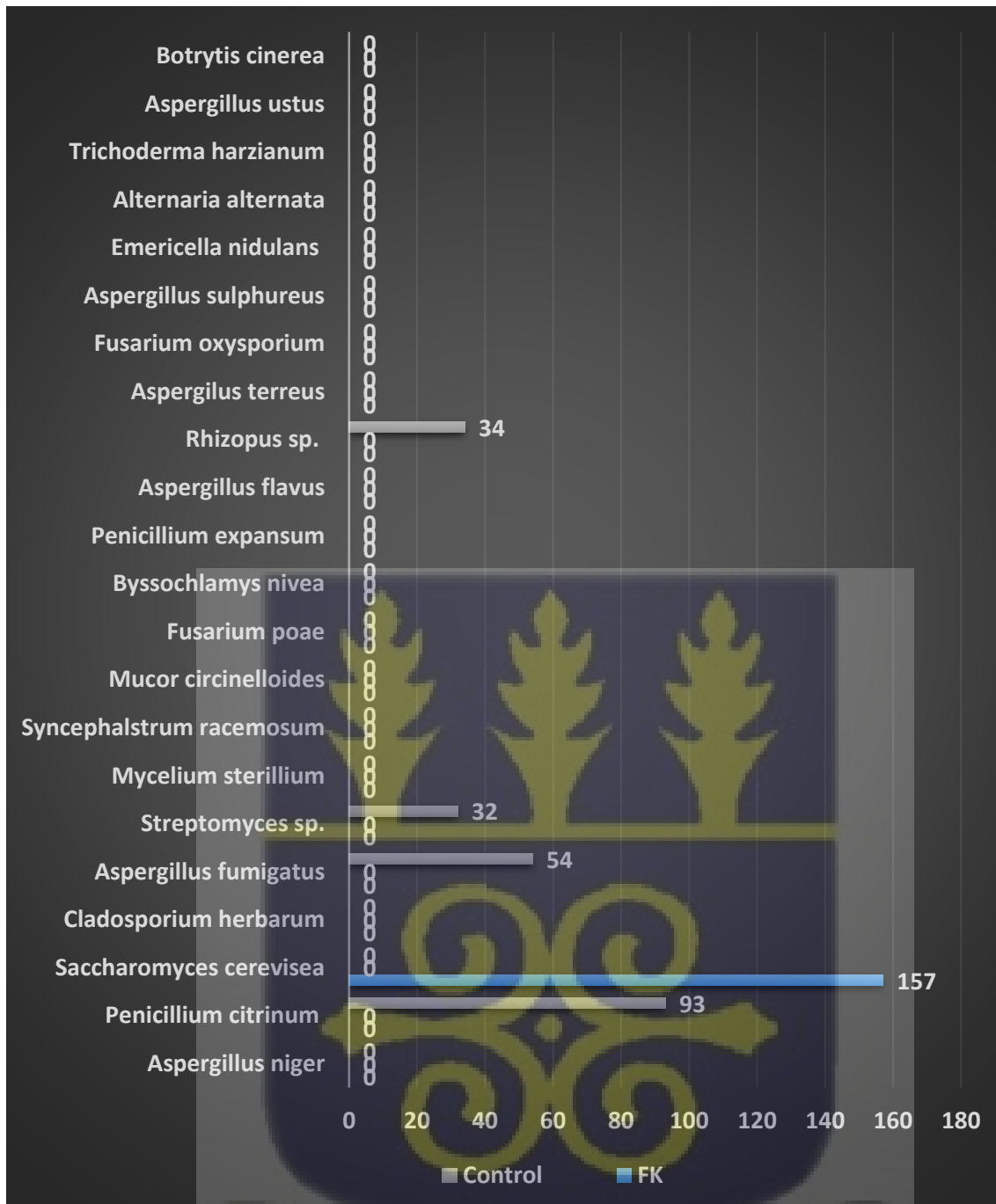


Figure 6: Soil Mycoflora of farms in Asewe in DG18 medium (fungi)

Interpretation of keys: FB- Farms from Kwabia Asasehene, FK-Farms from Kwabia and a control.

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

The soils have moderate moisture content with sandy clay loam, sandy loam and silty loam as the textural classes of the soils. Generally, organic matter and potassium nutrients were high whilst sodium, calcium and magnesium nutrients were moderate. The average pH was 6.04 with low electrical conductivity. The cation exchange capacity for the farms was moderate. Bacterial and fungal populations were present in numbers that reflect a gradual decline in fertility of the soils in the districts, thus leading to low agricultural productivity.

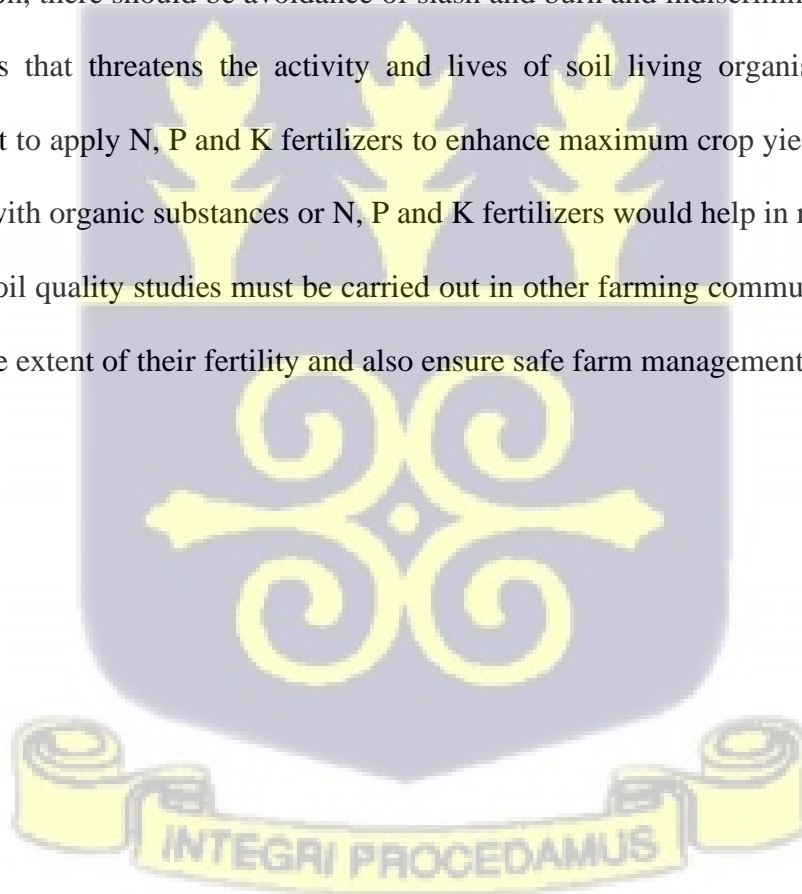
Some few farms contained appreciable population of microbes that can represent soils in good health, although most of the soils recorded very low microbes levels especially fungi in DG18 media. *Rhizopus stolonifer* and *Saccharomyces cerevisiae* were generally present in higher populations in pesticide treated soils compared to control groups.

It can be concluded from the test results that the soil in Asesewa farmslands though fit for agricultural productivity, lacks some nutrients. Quality assurance and quality control were incorporated in the whole analysis by running triplicate analysis, handling samples with care, calibration blanks and standards were also considered.



## 5.2 Recommendations

- To recover and sustain soil fertility of the land, there should be enough soil fertility monitoring of the soils or farms by MoFA extension officers at regular intervals and ensure plants residues and animal manure application to the soils. This would serve as feed for soil micro-organisms to produce ergosterol that aids in soil aggregation and increase productivity of the degrading soils. This would contribute to the formation of humus to reduce sand content and increase the water and nutrient holding and transportation capacity of the soil.
- In addition, there should be avoidance of slash and burn and indiscriminate application of pesticides that threatens the activity and lives of soil living organisms. It would be important to apply N, P and K fertilizers to enhance maximum crop yield. Also, fusion of the soil with organic substances or N, P and K fertilizers would help in revamping the soil CECs. Soil quality studies must be carried out in other farming communities in Ghana to assess the extent of their fertility and also ensure safe farm management practices.



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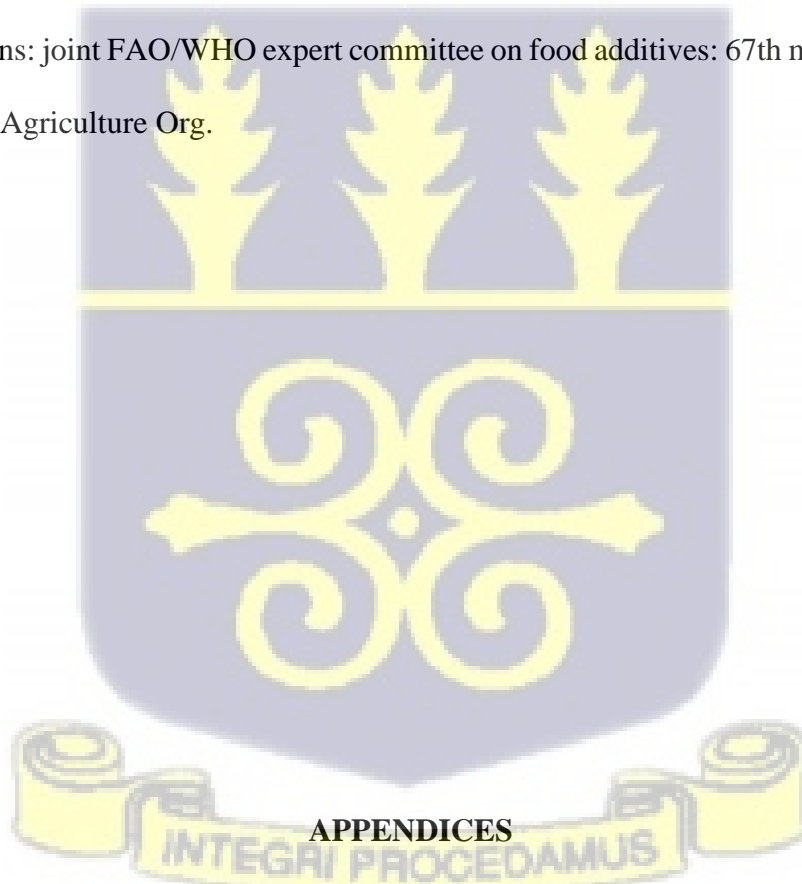
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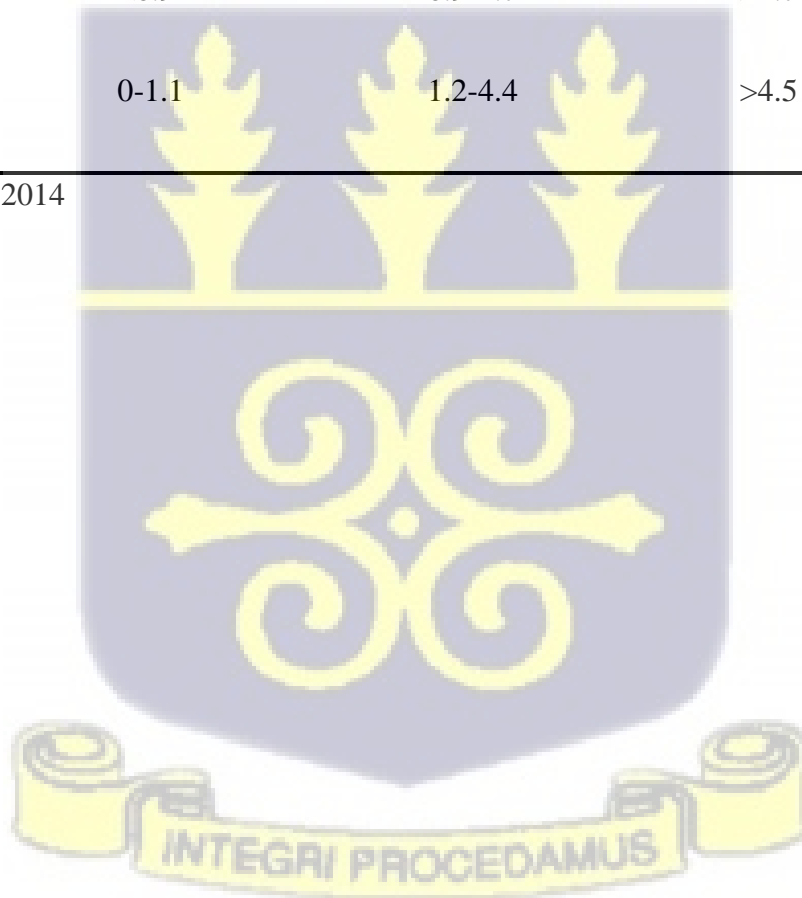
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APPENDIX 1: Standard soil parameter ranges for Exch. bases, EC, %OM and %OC

Soil Parameter	Low	Moderate	High
Ca(cmol+)/Kg	<5	5-10	>10
Mg(cmol+)/Kg	<1	1-5	>5
K(cmol+)/Kg	<0.5	0.5-1.0	>1.0
Na(cmol+)/Kg	<0.3	0.3-1.0	>1.0
% OC	<1.0	1.0-1.8	>3.0
% OM	<0.9	0.9-1.7	>1.7
EC(dS /m)	0-1.1	1.2-4.4	>4.5

Source: Proffitt, 2014



APPENDIX 2: Levels of exchangeable cations (cmol+)/kg

Cation	Very low	Low	Moderate	High	Very high
Ca	0-2	2-5	5-10	10-20	>20
Mg	0-0.3	0.3-1.0	1-3	3-8	>8
K	0-0.2	0.2-0.3	0.3-0.7	0.7-2.0	>2
Na	0-0.1	0.1-0.3	0.3-0.7	0.7-2.0	>2

Source: Metson (1961)



APPENDIX 3: Interpretation of pH ratings, Bruce and Rayment (1982)

PH	Ratings
>9.0	very strongly alkaline
9.0–8.5	strongly alkaline
8.4–7.9	moderately alkaline*
7.8–7.4	mildly alkaline
7.3–6.6	neutral
6.5–6.1	slightly acid
6.0–5.6	moderately acid
5.5–5.1	strongly acid
5.0–4.5	very strongly acid**



APPENDIX 4: Mycofloral profile for individual fungi species

Population of fungi for five farms each from Kwabia and KwabiaAsasehene soils in UpperManyaKrobo District in DG18 media

Mycoflora profile	FK	FB	Control
<i>Aspergillus niger</i>	0	0	0
<i>Penicilliumcitrinum</i>	0	0	93
<i>Saccharomyces cerevisea</i>	157	0	0
<i>Cladosporiumherbarum</i>	0	0	0
<i>Aspergillus fumigatus</i>	0	0	54
<i>Streptomyces sp.</i>	0	0	32
<i>Mycelium sterillium</i>	0	0	0
<i>Syncephalstrumracemosum</i>	0	0	0
<i>Mucorcircinelloides</i>	0	0	0
<i>Fusarium poae</i>	0	0	0
<i>Byssochlamysnivea</i>	0	0	0
<i>Penicilliumexpansum</i>	0	0	0
<i>Aspergillus flavus</i>	0	0	0
<i>Rhizopus sp.</i>	0	0	34
<i>Aspergилusterreus</i>	0	0	0
<i>Fusarium oxysporium</i>	0	0	0
<i>Aspergillus sulphureus</i>	0	0	0
<i>Emericellanidulans</i>	0	0	0
<i>Alternariaalternata</i>	0	0	0

<i>Trichoderma harzianum</i>	0	0	0
<i>Aspergillus ustus</i>	0	0	0
<i>Botrytis cinerea</i>	0	0	0
<i>Elutoriumglaucus</i>	0	0	0
<i>Aspergillus tamarrii</i>	0	0	0

**Population of fungi in soil for five farms each from Kwabia and KwabiaAsasehene in Upper ManyaKrobo District in Malt Extract Agar**

Mycoflora profile	FK	FKA	Control
<i>Aspergillus niger</i>	90	84	0
<i>Penicilliumcitrinum</i>	0	0	93
<i>Saccharomyces cerevisea</i>	91	72	0
<i>Cladosporiumherbarum</i>	0	33	0
<i>Aspergillus fumigatus</i>	120	124	54
<i>Streptomyces sp.</i>	0	0	32
<i>Mycelium sterillium</i>	47	66	0
<i>Syncephalstrumracemosum</i>	0	0	0
<i>Mucorcircinelloides</i>	0	0	0
<i>Fusarium poae</i>	0	0	0
<i>Byssochlamysnivea</i>	42	40	0
<i>Penicilliumexpansum</i>	0	0	0
<i>Aspergillus flavus</i>	84	0	0
<i>Rhizopusstolonifer</i>	101	176	34
<i>Aspergilusterreus</i>	0	0	0
<i>Fusarium oxysporium</i>	0	0	0

<i>Aspergillus sulphureus</i>	0	0	0
<i>Emericellanidulans</i>	0	0	0
<i>Alternariaalternata</i>	0	0	0
<i>Trichoderma harzianum</i>	0	76	0
<i>Aspergillus ustus</i>	0	0	0
<i>Botrytis cinerea</i>	0	0	0
<i>Elutoriumglaucus</i>	0	0	0
<i>Aspergillus tamaraii</i>	0	0	0



APPENDIX 5: Photography



Operation of Kjeldahl distillation plant



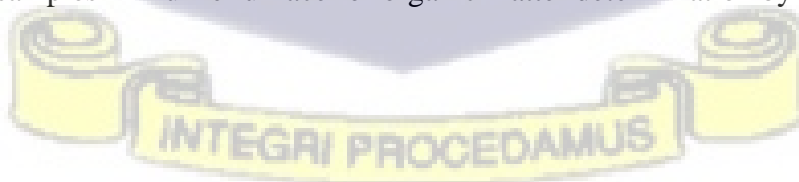
**Filtration of samples for the determination of exchangeable bases**



**Cooling of samples in a desiccators for soil organic matter analysis**



Arrangement of samples in muffle furnace for organic matter determination by loss on ignition





Preparation of soil samples in the laminar flow for total microbial population

