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DEPARTMENT OF DEVELOPMENT STUDIES

A COMPARATIVE STUDY OF CHANGES IN SOIL QUALITY UNDER TWO CROPPING SYSTEMS IN SANTA, NORTH WEST REGION, CAMEROON.

A Thesis Submitted to the Department of Development Studies, in Partial Fulfilment of the Requirements for the Award of a Master of Science (M.Sc) Degree in Environment and Natural Resource Management

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Buea, January 2016

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This work is dedicated to my father, Mr. Naseli Bau Okha and to the Atabong family.

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Abstract

The influence of two cropping systems (mono and mixed cropping) on soil physical and chemical properties was investigated in some farm lands in Santa. The specific aims were to find out the physical and chemical characteristics of soils under mixed and mono-cropping systems in Santa, to compare their fertility status in relation to their physical and chemical characteristics, and also to look at challenges faced by farmers practicing these cropping systems in Santa. Soil samples collected between depths of 0-20cm with the use of a soil augar on level land from plots under the two cropping systems and preserved in separate zip lock plastic bags were subjected to physico-chemical analyzes at the science research laboratory of the University of Dschang. The results indicate variations and similarities in the physical and chemical characteristics of soils under both cropping systems. Soils under mixed cropping had higher levels of Organic Matter (6.11 %), Cation Exchange Capacity (14.62 %), and Exchangeable Bases (Ca: 22.6 Cmol (+) kg, Mg: 1.50 Cmol (+) kg, and Na: o.39 Cmol (+) kg). Whereas soils under mono-cropping systems had lower pH (5.59), Exchangeable Bases (Ca: 1.66 Cmol (+) kg, Mg: 1.3 Cmol (+) kg, and Na: 0.02 Cmol (+) kg), and Cations Exchange Capacity (11.39 %). Bulk Density, Electrical Conductivity, total Nitrogen, Carbon to Nitrogen ratio, Calcium, Potassium and available phosphorus were not significantly different ($p>0.05$) for both cropping systems. Whereas Cation Exchange Capacity, Sodium, Magnesium, pH, and Exchangeable Acidity were significantly different ($p<0.05$) for soils under both cropping systems. Soil nutrient shortages, soil acidity, soil compaction (formation of hard pans), loss of top soil, shortage of water and destruction of irrigation pipes by cattle were some of the challenges faced by farmers who practiced these cropping systems in Santa. Mixed cropping is good in enhancing soil fertility through the reduction in soil erosion and higher organic matter build-up.

Key words: Physico-chemical characteristics, cropping system, soil fertility.

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Acronyms and Abbreviations

CROPT:	Climate, Relief, Organisms, Parent material, and Time.
SSA:	Sub Saharan Africa.
LUCC:	Land Use and Land Cover.
GDP:	Gross Domestic Product.
OM:	Organic Matter.
FC:	Field Capacity.
PWP:	Permanent Wilting Point.
EC:	Electrical Conductivity.
CEC:	Cation Exchange Capacity.
CDC:	Cameroon Development Corporation
ANOVA:	Analysis of Variance.
BD:	Bulk Density.
AV.P :	Available Phosphorus.
AV.N :	Available Nitrogen.
AV.K:	Available Potassium
AWHC:	Available Water Holding Capacity.
C/N:	Carbon to Nitrogen Ratio.
FAO:	Food and Agricultural Organization.
UN:	United Nations.
FIG:	Figure.
OC:	Organic Carbon.
WWF:	World Wide Fund.
INS:	National Institute of Statistics of Cameroon.
IFPRI:	International Food Policy Research Institute.
ZT:	Zero Tillage.
CA:	Conservable Agriculture.
Ca:	Calcium
Na:	Sodium

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Land use involves the manner in which the biophysical attributes of the land are manipulated (Lambi *et al.*, 2003). In most countries of Sub-Saharan Africa, about 60 percent of the economically active population works in the agricultural sector. Over 85% of the rural population of Sub-Saharan Africa continues to rely on agriculture for their survival (Mahendra *et al.,* 2008). Rates of agricultural expansion are decreasing globally but still expanding in Sub-Saharan Africa (SSA). This could be attributed to unsustainable farming practices leading to land degradation and subsequently a decline in the soil's fertility status, thus influencing farmers to cut more of the forest areas in search of suitable land (fertile land). It is estimated that 70% of the grasslands, 50% of the savanna, 45% of the temperate deciduous forests and 27% of the tropical forests have been cleared for agriculture (Foley *et al.,* 2011). Ecological footprint has affected about 83% of the global terrestrial land surface and has degraded about 60% of the ecosystems services in the past 50 years alone (Bruinsma, 2009). Land use and land cover (LUCC) change has been the most visible indicator of the human footprint and the most important driver of loss of biodiversity and other forms of land degradation. Between 1992 and 2009, agricultural land area increased by about 4% in Sub Saharan Africa (SSA) (Bruinsma, 2009). The challenge of feeding the world's growing population without further damaging the natural resource base is becoming increasingly urgent, and must be met in ways that also allow adaptation to and mitigation of soil fertility. Land use in tropical ecosystems could cause significant modifications in soil properties (V. Agoume and A. M. Birang, 2009).

Agriculture provides not only food but also fuel, fibre and a wide range of ecosystem services. Sustainable agricultural practices in this sector would tantamount to an increase in rural incomes and purchasing power of a vast number of the population in the region. This would reduce poverty and hunger, and ensure sustainable development (IFPRI, 2006). Soil fertility is a key constraint to improving farm productivity and farmer livelihoods in Sub-Saharan Africa (Nigeriasoilhealthconsortium.com). In Cameroon, agriculture remains the backbone of the country's economy and employs more than 70% of its population (Molua & Lambi, 2006; Kimengsi & Muluh, 2013; Kimengsi & Tosam, 2013).Cameroon produces both cash and food crops through government corporations like the Cameroon Development Corporation (CDC) or by individuals who carry out peasant agricultural production. However, this activity has been mostly affected by oscillations in the local climatic elements especially rainfall and temperature which have effects on both plantation and peasant agriculture (Molua & Lambi, 2006; Kimengsi & Muluh, 2013; Kimengsi & Tosam, 2013).

Soil fertility maintenance is a major concern in sub -Saharan Africa, particularly with the rapid population increase, which has been witnessed in the past few decades (Gebeyaw. T, 2015). Cropping systems affect soil chemical, physical and biological properties, which alters soil fertility. In traditional farming systems, farmers use bush fallow, plant residues, household refuse, animal manures and other organic nutrient sources to maintain soil fertility and soil organic matter. (Wasihun *et al.*, 2015).

Cameroon lies in sub-Saharan Africa, located on the Gulf of Guinea, between latitudes 1.7^{o}N–13.8^{o}N and longitudes 8.4^{o}E–16.8^{o}E. It has five major agro-ecological zones: the inland equatorial forest, equatorial maritime forest, highland tropical, Guinea-savannah, and Sudan savannah. These zones represent a majority of the agro-ecological zones within which small-scale food production is practiced in sub-Saharan Africa. Being a dominant sector of the national economy, agriculture currently contributes about 52 % to GDP, 45 % of export earnings, and 15 % in public revenue (INS, 2010). Santa is one of the 32 sub divisions of the North West Region which is located between latitudes 5° 42´and 5° 53´ N of the Equator and longitudes 9° 58´ and 10° 18´ E of the Greenwich Meridian (Kimengsi, 2015)). It covers some nine villages, namely, Mbei, Njong, Akum, Mbu (Baforchu), Alatening, Baba, Awing, Baligham, and Pinyin. Located in the Western Highlands of Cameroon, it covers a surface area of about 532.67 km^2. It is bordered to the North by Bamenda 1 and 2 Sub Division, to the West by Bali and Batibo Sub-Divisions, to the South by Wabane, Babadjou, and Mbouda, and to the East by Galim. It lies some 20km from Bamenda and is disenclaved by the national road number 10 which links Bamenda to Bafoussam and the rest of the country and sub-region (Kimengsi, 2015).

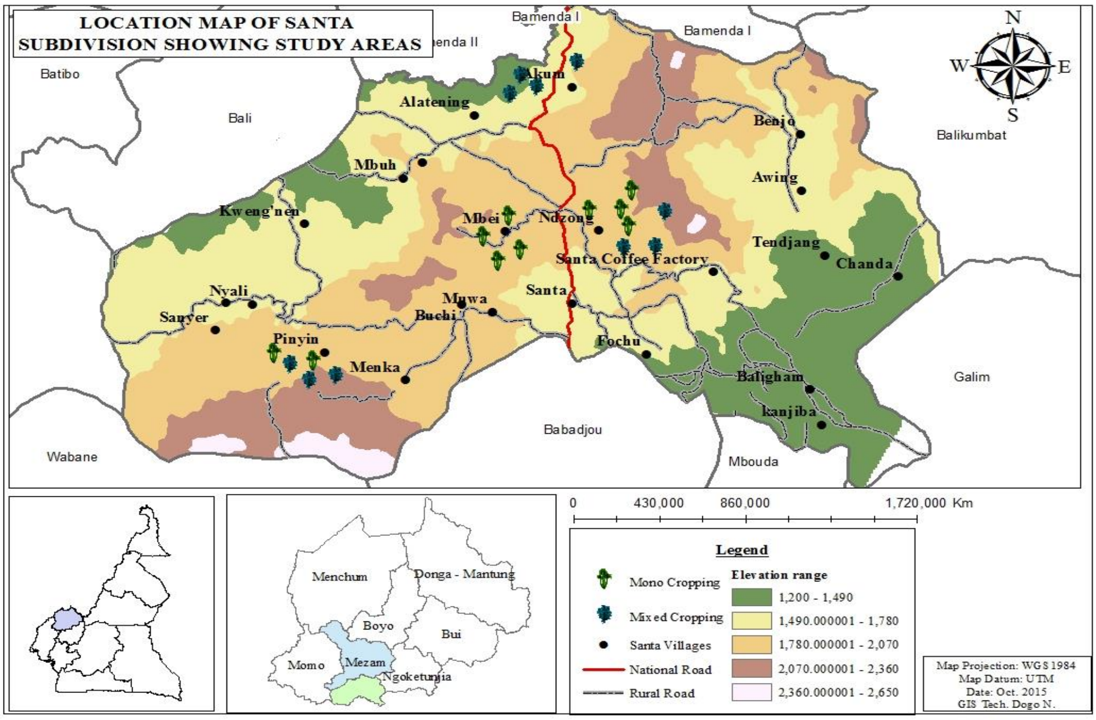


Figure 1.1 Location map of Santa Subdivision showing study areas

Although the reliance on organic nutrient sources for soil fertility regeneration is adequate with low cropping intensity, it becomes unsustainable with more intensive cropping unless fertilizers are applied (Mulongey and Merck, 1993).Reducing degradation, increasing agricultural productivity, reducing poverty, and achieving food security are major developmental challenges of the countries in sub-Saharan Africa. Thus, every effort should be directed to maintain the physical, biological and socio- economic environment for production of food crops, livestock, wood and other products through sustainable use of the ecosystem.

1.2 Problem statement

Food and nutritional insecurity remain a significant challenge in many regions of the World. The need to improve food security is particularly urgent in Sub-Saharan Africa and Asia, as well as in some countries in Latin America and the Caribbean, which account for almost 90 % of the under nourished people in the world, most of them in rural settings (CIFSRF, 2015). There are about 1020 million food-insecure people in the world (FAO, 2000). An additional 3.4 billion people suffer from hidden hunger because of the intake of food grown on poor quality soils (Rattan. L, 2015). Globally, food production must be doubled by 2050 to meet the increasing demand of the growing world population.

It is estimated that present global agricultural production must increase by 70–100 % to feed over 9000 million people by2050 (Dubois, 2011). It is forecast that the world will suffer a slowdown in the annual growth of crop production, from 2.2 to1.1 % globally, and from 3.0 to 1.2 % in developing countries from 2006 to 2050 (Yengoh. G, 2014). Average annual crop yield growth within this period will halve from 1.7 to 0.8 %and from 2.1 to 0.9 %, respectively (Bruinsma, 2009). The World Bank has estimated that under current conditions, global food production will need to double by 2050 to meet increasing global needs.

Cameroon, like much of sub-Saharan Africa, is undergoing a demographic and economic transformation that stands to change the quantity and types of food demanded (Thornton *et al.*, 2011, Tilman *et al.*, 2011). With an annual population growth rate of about 2.8 % and an urbanization rate of 52 % in2010 (INS, 2010), food production is likely to face numerous challenges, including in particular competition for land with other uses, an increase in the total amount of food demanded, and changes in dietary preferences(Yengoh. G, 2014).

Santa sub division contributes in no small measure to food security in the Central African sub-Region. Crops mostly grown in this sub division includes maize, irish and sweet potatoes, beans, cabbage, green spices, carrot, vegetables, cocoayam, yams, cassava, and tomatoes. These crops can be consumed by all, infants, adults and even the aged persons, and provide more food energy. In their natural form, they are a rich source of vitamins, minerals, carbohydrates, fats, oils, and protein. Unfortunately, these crops cannot be grown in greater quantities if the soil is infertile. The application of chemical fertilizers poses serious environmental and health threats.

Changes in cropping systems and soil management can have a marked effect on the soil fertility. Unsustainable cropping and farming practices can lead to serious reduction in soil fertility (Manu *et al.*, 2014). In the face of growing food demand and constraints of available resources (such as cultivable land, water and energy), it is not possible to produce increasingly higher quantities of nutritious food without assessing the physico-chemical status of soils under mixed and mono-cropping systems, and thus the introduction of sustainable methods of soil fertility improvement, that enhances the development of improved sustainable food production (CIFSRF, 2015).

1.3 Objectives

1.3.1 Main objective

To compare changes in soil quality under mixed and mono-cropping systems, in some farm lands in Santa Sub-division, North West region of Cameroon.

1.3.2 Specific objectives

- To characterize soils under mixed and mono-cropping systems in Santa.
- To compare the fertility status of soils under mixed and mono-cropping systems in Santa.
- To identify challenges faced by farmers practicing mixed and mono-cropping systems in Santa.

1.4 Research questions

- What are the physico-chemical characteristics of soils under mixed and mono-cropping practices in Santa?
- What is the fertility status of soils under mixed and mono-cropping systems in Santa?
- What challenges do farmers practicing mixed and mono-cropping systems in Santa sub-division face?

1.5 Significance of the study

Maintaining and improving soil quality is crucial if agricultural productivity and environmental quality are to be sustained for future generations (Reeves. D, 1997). Research on assessing the physico-chemical status of soils under mixed and mono cropping systems in Santa will be of importance to:

- Research: Soil quality data concerning their physico-chemical properties under mixed and mono cropping systems in Santa will be available.

- Policy: It will provide policy makers with important information on the quality of soils under mixed and mono cropping systems in Santa. This will provide a means for timely actions on soil quality amelioration policies in this area to ensure continuous food production and thus prevent food insecurity in this area.

- Farmers: Information on the physico-chemical status of soils under mono and mixed cropping systems will be available to farmers practicing these cropping systems. This will, therefore, create an awareness on their unsustainable farming practices that reduces soil quality. Also sustainable measures that improve soil quality will be available to them, providing them with more options on improving and maintaining soil fertility, other than the high reliance on inorganic fertilizer application, use of irrigation systems and use of animal droppings.

1.6 Scope of the study

The two main cropping systems under this study include: mono-cropping and mixed cropping systems. Although this study was carried out in Santa sub-division, it focused only on four villages namely; Njong, Mbei, Pinyin and Akum villages. Soil quality parameters were based on the physical and chemical characteristics. These physical and chemical characteristics were limited to bulk density, texture, porosity, pH, electrical conductivity, exchangeable acidity, exchangeable cations, total nitrogen, cations exchange capacity, organic matter and available phosphorus.

1.7 Organization of the study

This work has five (5) Chapters. Chapter one (1) describes the back ground of the study, the statement of the problem, objectives of the study, research questions that seek to answer the objectives, scope of the study, and also explains significance of the study. Chapter two (2) reviews literature on soil, soil profile, soil's physical and chemical properties, cropping systems, and lastly sustainable farming practices that enhance soil fertility. Chapter three (3) describes the research materials and methods used to carry out the study. Chapter four (4) presents the results and study discussions of the findings. And chapter five (5) gives summary of findings, conclusion, suggested areas for further research, and recommendations.

1.8 Definition of terms

Land use

Land use involves the manner in which the biophysical attributes of the land are manipulated (Lambi *et al*., 2003).

Suitable land

FAO's Global Agro-Ecological Zone (GAEZ) defines suitable land as land with soil, terrain and climate characteristics which meet the crop production requirements with specified input levels.

Ecosystem services

Ecosystem services are the "components of nature, directly enjoyed, consumed, or used to yield human wellbeing" (Stockholmresilience.org).

Ecological foot prints

The ecological footprint is a measure of the biologically productive land area and water required to provide food, feed, fiber, timber, energy and to absorb CO2 waste under current technology (WWF, 2012).

Land degradation

Loss of the capacity of land to provide ecosystem services (Bai *et al.,* 2008)

Cropping system

The term cropping system refers to the crops and crop sequences and the management techniques used on a particular field over a period of years (Emerson, 2005).

Mono-cropping

Mono-cropping refers to the presence of a single crop in a field. This term is often used to refer to growing the same crop year after year in the same field; this practice is better described as continuous cropping, or continuous mono-cropping (Emerson, 2005).

Mix cropping

Growing of two or more crops simultaneously on the same piece of land without any particular row arrangement season after season (Balarabe, 2008).

Soil

Soil is a mixture of minerals, organic matter, gases, liquids and a myriad of organisms that can support plant life (Johnson *et al.*, 2005).

Soil fertility

Soil fertility is "the quality of a soil that enables it to provide nutrients in adequate amounts and proper balance for the growth of specified plants or crops". (SSSA, 1997).

Agriculture

Agriculture is defined as the art, the science and the business of producing crops and the livestock for economic purposes (Agriculture Act, 1947).

Food security

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. (World Food Summit, 1996).

Arable land

Arable land describes farm land suitable for or use for growing crops (Cambridge advanced learners dictionary, 2008).

CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Literature review

2.1.1 Soil

Soil is a mixture of minerals, organic matter, gases, liquids and a myriad of organisms that can support plant life. It performs four important functions: it is a medium for plant growth; it is a means of water storage, supply, and purification; it is a modifier of the atmosphere, and it is a habitat for organisms that take part in decomposition organic materials. Soil is said to be formed when organic matter has accumulated, and colloids are washed downward, leaving deposits of clay, humus, iron oxide, carbonate, and gypsum. Soil consists of a solid phase (minerals & organic matter) as well as a porous phase that holds gases and water. Soil continually undergoes development by way of numerous physical, chemical and biological processes, which include weathering with associated erosion. Most soils have a density between 1 and 2 g/cm^3(Johnson *et al.,* 2005).

2.1.2 Soil profile

The soil profile is a vertical section of the soil from the ground surface downwards to where the earth meets the underlying rock (Johnson *et al.*,2005). The alteration and movement of materials within a soil causes the formation of distinctive soil horizons. The soil profile can be as little as 10 cm thick in immature soils and as deep as several metres in tropical areas where the climate is conducive to rapid alteration of the underlying rock to form soil (*Johnson et al.,* 2005). The horizons differ considerably in thickness and lack sharp boundaries. The differentiation of the soil into distinct horizons is largely the result of influences such as parent material, climate, topography (relief), organisms, and time. When reordered to climate, relief, organisms, parent material, and time, they form the acronym CROPT. Since the weathering of soil occurs first at the surface and works its way down, the uppermost layers have been changed the most, while the deepest layers are most similar to the original regolith (Johnson *et al.*,2005).

Virtually all soil profiles are composed of some distinctive layers, termed horizons. Most soils will have three or more horizons. Soils that have not been cultivated will normally have L, F and H layers at the surface. These layers largely represent different degrees of decomposition of organic matter. The L layer representing the litter layer formed of recognizable plant and soil animal remains. The F layer below the L layer, the fermentation layer, usually consisting of a mixture of organic matter in different stages of decomposition. The H layer beneath the F layer, the humus layer, composed largely of humified material with little or no plant structure visible. Below these layers, and in cultivated soils occupying the surface layer, is the A horizon composed of a more or less intimate mixture of mineral and organic matter (Johnson *et al.*,2005).

The A horizon is often referred to as the 'ploughed layer' (surface soil) in cultivated soils. A-horizons may also be the result of a combination of soil bioturbation and surface processes that winnow fine particles from biologically mounded topsoil. In this case, the A-horizon is regarded as a 'biomantle'. It is an important part of the soil because it is a source of plant nutrients and contains the majority of plant roots. The A horizon may lie directly on the B horizon, or in well-developed soils; there may be an intermediate leached horizon, termed E or A2, depending on the nomenclature system used. The E/A2 horizon is usually paler in color than the horizons above and below because it is the horizon that has been subject to leaching and loss of components compared to the A and B horizons (Johnson *et al.,* 2005).

The B horizon is the horizon most widely used to identify soil types. It is also known as subsoil. Subsurface layer that reflects chemical or physical alteration of parent material. This layer accumulates iron, clay, aluminum and organic compounds, a process referred to as illuviation. The B horizon may also have stronger colors (higher chroma) than the A horizon. Plant roots penetrate through this layer, but it has tiny humus. It is usually brownish or reddish due to clay and iron oxides that wash down from A horizon. Its morphology is important in supporting the classification of soils. In some soils, the B horizon results purely from the weathering of the underlying rock whereas in others this weathering is supplemented by the translocation of materials from overlying horizons. Thus, the B horizon needs to be inspected carefully in order to understand the genesis of the soils. B horizons may have a number of different subscripts indicative of the nature of the materials that have moved into the horizon, *e.g.* Bh indicates the translocation of humus into the horizon, Bs the translocation of sesquioxides. These subscripts will vary according to the nature of the soil component that has accumulated but also with the system of nomenclature of soil types (Johnson *et al.*, 2005).

The C horizon which is below the B horizon is largely composed of the Parent rock. It is also referred to as the Layer of large unbroken rocks. This layer may accumulate more soluble compounds. This horizon is often consistent with the parent material and may have been little altered from the material in which the soil originally formed. The C horizon is below the zones of greatest biological activity and it has not been sufficiently altered by soil genesis to qualify as a B horizon. In dry regions, carbonates and gypsum may be concentrated in the C horizon. While loose enough to be dug with a shovel, C horizon material often retains some of the structural features of the parent rock or geologic deposits from which it formed (Johnson *et al.*, 2005).

Most soils have A, B and C horizons. Some weakly developed soils may have A horizons lying directly on C horizons.

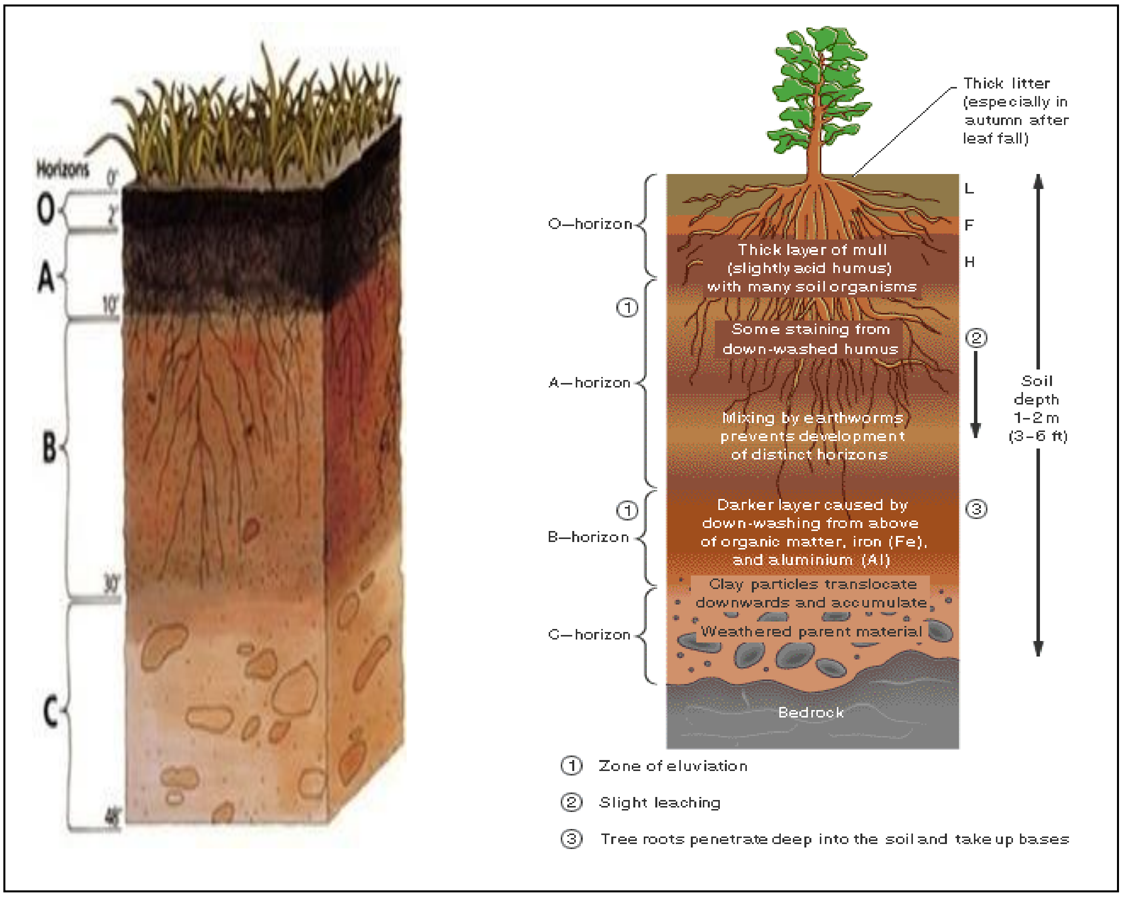


Figure 2.1: Representation of a soil profile

Source: (Johnson *et al.*, 2005).

2.1.3 Soil physical properties

The physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants. Many soil physical properties change with changes in land use system and its management such as intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion losses (Sanchez, 1976).

2.1.3.1 Soil texture

Soil texture determines a number of physical and chemical properties of soils. It is the distribution of the different sizes of mineral particles in a soil. Textures range from clay, sand, and silt at the extremes, to a loam which has all three sized fractions present. Soil texture is an innate property of the soil that does not change with agricultural activities. The main influence of texture is on permeability which generally decreases with decreasing particle size. It affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices (Foth, 1990; Gupta, 2004). It is also an indicator of some other related soil features such as type of parent material, homogeneity and heterogeneity within the profile, migration of clay and intensity of weathering of soil material or age of soil (Miller and Donahue, 1995; Lilienfein *et al.*, 2000).

Soil texture is one of the natural soil physical properties less affected by management. The rate of increase in stickiness or ability to mould as the moisture content increases depend on the content of silt and clay, the degree to which the clay particles are bound together into stable granules and the OM (organic matter) content of the soil (White, 1997). Over a very long period, pedogenic processes such as erosion, deposition, eluviations and weathering can change the textures of various soil horizons(Forth, 1990; Brady and Weil, 2002).

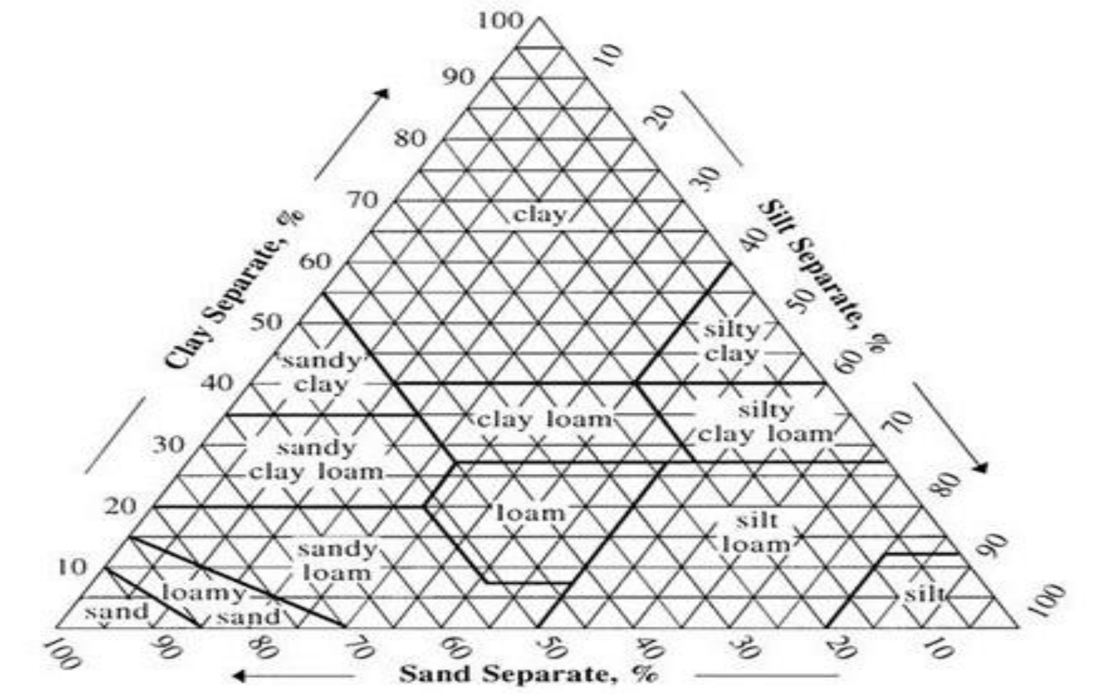


Figure 2.2: Soil texture triangle

Source: (Johnson *et al.,* 2005).

2.1.3.2 Soil structure

The clumping of the soil textural components of sand, silt and clay forms aggregates and the further association of those aggregates into larger units forms soil structures called peds. The adhesion of the soil textural components by organic substances, iron oxides, carbonates, clays, and silica, and the breakage of those aggregates due to expansion-contraction, freezing-thawing, and wetting-drying cycles shape soil into distinct geometric forms. These peds evolve into units which may have various shapes, sizes and degrees of development. The soil structure affects aeration, water movement, and conduction of heat, plant root growth, and resistance to erosion. Water has the strongest effect on soil structure due to its solution and precipitation of minerals and its impact on plant growth. Soil structure often gives clues to its texture, organic matter content, biological activity, past soil evolution, human use, and the chemical and mineralogical conditions under which the soil formed. Soil structure can be improved or destroyed by the choice and timing of farming practices (Johnson *et al.,* 2005).

2.1.3.3 Bulk and particle densities

Measurement of soil bulk density (the mass of a unit volume of dry soil) is required for the determination of compactness, as a measure of soil structure, for calculating soil pore space and as indicator of aeration status and water content (Barauah and Barthakulh, 1997). Bulk density also provides information on the environment available to soil microorganisms. White (1997) stated that values of bulk density ranges from < 1 g/cm^{3}for soils high in OM, 1.0 to1.4g/cm^{3}for well- aggregated loamy soils and 1.2 to 1.8 g/cm^{3}for sands and compacted horizons in clay soils. Bulk density normally decreases as mineral soils become finer in texture. Soils having low and high bulk density exhibit favorable and poor physical conditions, respectively.

Bulk densities of soil horizons are inversely related to the amount of pore space and soil OM (Brady and Weil, 2002; Gupta, 2004). Any factor that influences soil pore space will also affect the bulk density. For instance, intensive cultivation increases bulk density resulting in reduction of total porosity.

Particle density is the mass or weight of a unit volume of soil solids. It affects soil porosity, aeration and rate of sedimentation of particles. The mean particle density of most mineral soils is about 2.60 to 2.75 g/cm^3, but the presence of iron oxide and heavy minerals increases the average value of particle density and the presence of OM lowers it (Hillel, 1980).

2.1.3.4 Total porosity

The total porosity of soils usually lies between 30% and 70%. In soils with the same particle density, the lower the bulk density, the higher is the percent total porosity. As soil particles vary in size and shape, pore spaces also vary in size, shape and direction (Foth, 1990). Coarse textured soils tend to be less porous than fine texture soils, although the mean size of individual pores is larger in the former than in the latter.

There is close relationship between relative compaction and the larger (macro-pores) of soils (Ike and Aremu, 1992). According to the same authors, tillage reduces the macro-pore spaces and produces a discontinuity in pore space between the cultivated surface and the subsurface soils. Intensive cultivation causes soil compaction and degradation of soil properties including porosity. Macro-pores can occur as the spaces between individual sand grains in coarse textural soils. Thus, although a sand soil has relatively low total porosity, the movement of air and water through such soil is surprisingly rapid because of the dominance of macro-pores. Fertile soils with ideal conditions for most crops have sufficient pore space, more or less equally divided between large (macro) and small (micro) pores. The decreasing OM and increasing in clay that occurs with depth in many soil profiles are associated with a shift from macro-pores to micro-pores (Brady and Weil, 2002). Micro-pores are water filled; and they are too small to permit much air movement. Water movement in micro-pores is slow, and much of the water retained in these pores is not available to plants. Fine textured soils, especially those without a stable granular structure may have a dominance of micro-pores, thus allowing relatively slow gas and water movement, despite the relatively large volume of total pore space (Landon, 1991).There are four categories of pores:

i. Very fine pores: < 2 μm
ii. Fine pores: 2-20 μm
iii. Medium pores: 20-200 μm
iv. Coarse pores: 200 μm-0.2 mm

2.1.3.5 Soil water content and retention capacity

Soil water enhances various soil physico-chemical reactions and supplies essential nutrients for plants and animals including micro and macro organisms residing in soils in order that they can carry out their activities (Tisdale *et al.*, 1995). The portion of stored soil water that can readily be absorbed by plants is said to be available water. The plant available soil water is held within a potential between field capacity (FC) and permanent wilting point (PWP). Available soil water content is greatly influenced by soil OM content, texture, mineralogy and soil morphology (Landon, 1991). According to Teklu (1992), soils with high amount of clay have greater amount of water, than soils with low amount of clay content and thus water retention capacity of a soil is a function of silicate clays and amorphous materials. Water occupies the soil pore spaces and is adsorbed to soil particles. Variation in topography, land use and soil attributes all affect the distribution of soil moisture (Ahmed, 2002; Brady and Weil, 2002).

2.1.3.6 Soil temperature

Soil temperature depends on the ratio of the energy absorbed to that lost. Soil has a temperature range between -20 to 60°C. Soil temperature regulates seed germination, plant and root growth and the availability of nutrients. Below 50 cm, soil temperature seldom changes and can be approximated by adding 1.8°C to the mean annual air temperature. Soil temperature has important seasonal, monthly and daily variations. Fluctuations in soil temperature are much lower with increasing soil depth. Heavy mulching (a type of soil cover) can slow the warming of soil, and at the same time, reduce fluctuations in surface temperature (Johnson *et al.,* 2005).

Various factors affect soil temperature, such as water content, soil color, and relief (slope, orientation, and elevation), and soil cover (shading and insulation). The color of the ground cover and its insulating properties has a strong influence on soil temperature. Whiter soil tends to have a higher albedo than blacker soil cover, which encourages whiter soils to have cooler soil temperatures. The specific heat of soil is the energy required to raise the temperature of soil by 1°C. The specific heat of soil increases as water content increases, since the heat capacity of water, is greater than that of dry soil. The specific heat of pure water is ~ 1 calorie per gram, the specific heat of dry soil is ~ 0.2 calories per gram and the specific heat of wet soil is ~ 0.2 to 1 calories per gram. Also, tremendous energy (~540 cal/g) is required and dissipated to evaporate water (known as the heat of vaporization). As such, wet soil usually warms more slowly than dry soil - wet surface soil is typically 3 to 6°C colder than dry surface soil (Johnson *et al.*, 2005).

2.1.3.7 Soil color

Soil color is often the first impression one has when viewing soil. Striking colors and contrasting patterns are especially noticeable. In general, color is determined by the organic matter content, drainage conditions, and degree of oxidation. Soil color, while easily discerned, has little use in predicting soil characteristics. It is of use in distinguishing boundaries within a soil profile, determining the origin of a soil's parent material, as an indication of wetness and waterlogged conditions, and as a qualitative means of measuring organic, salt and carbonate contents of soils (Johnson *et al.,* 2005).

Soil mineralogy primarily influences soil color. Many soil colors are due to various iron minerals. The development and distribution of color in a soil profile result from chemical and biological weathering, especially redox reactions. As the primary minerals in soil parent material weather, the elements combine into new and colorful compounds. Iron forms secondary minerals of a yellow or red color. Organic matter decomposes into black and brown compounds, and manganese, sulfur and nitrogen can form black mineral deposits. These pigments can produce various color patterns within a soil. Aerobic conditions produce uniform or gradual color changes while reducing environments (anaerobic) result in rapid color flow with complex, mottled patterns and points of color concentration(Johnson *et al.,* 2005).

2.1.3.8 Resistivity

Resistivity refers to the resistance to conduction of electric currents and affects the rate of corrosion of metal and concrete structures. The electrical resistivity of soil can affect the rate of galvanic corrosion of metallic structures in contact with the soil. Higher moisture content or increased electrolyte concentration can lower resistivity and increase conductivity, thereby increasing the rate of corrosion. Soil resistivity values typically range from about 2 to 1000 Ω·m, but more extreme values are not unusual (Johnson *et al.*, 2005).

2.1.4 Soil chemical properties

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of soil to plants. The chemical reactions that occur in the soil, affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime, release chemical elements that undergo various changes and transformations within the soil. Below are some of the chemical properties of soil.

2.1.4.1 Soil reaction (pH) and electrical conductivity

Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and biological environment. Soil reaction affects nutrient availability and toxicity, microbial activity, and root growth. Thus, it is one of the most important chemical characteristics of the soil because both higher plants and microorganisms respond so markedly to their chemical environment.

Descriptive terms commonly associated with certain ranges in pH are: extremely acidic (pH <4.5), very strongly acidic (pH 4.5-5.0), strongly acidic (pH 5.1-5.5), moderately acidic (pH 5.6-6.0), slightly acid (pH 6.1-6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4-7.8), moderately alkaline (pH 7.9-8.4), strongly alkaline (pH 8.5-9.0), and very strongly alkaline (pH > 9.1) (Foth and Ellis, 1997).

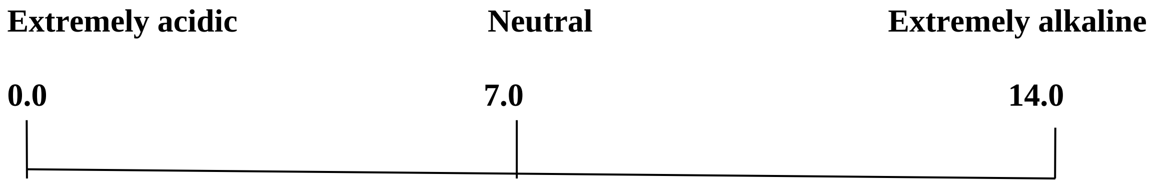


Figure 2.3: pH scale

Source: (Foth and Ellis, 1997).

The degree and nature of soil reactions are influenced by different anthropogenic and natural activities including leaching of exchangeable bases, acid rains, decomposition of organic materials, application of both organic and inorganic fertilizers, and farming practices (Tisdale *et al.*, 1995).

In strongly acidic soils, Al^{3+} becomes soluble and increase soil acidity while in alkaline soils; exchangeable basic cations tend to occupy the exchange sites of the soils by replacing exchangeable H^+ and Al^{3+} (Miller and Donahue, 1995).

Electrical conductivity (EC) is a measure of salinity. In addition to overcoming some of the ambiguities of total dissolved salts measurements, the EC measurement is quicker and sufficiently accurate for most purposes (Bohn *et al.*, 2001). Excessive accumulation of soluble salts convert soils to salt affected soils and the process leading to accumulation of salts are common in arid and semi-arid regions where rainfall amount is insufficient to leach soluble salts.

2.1.4.2 Soil organic matter

Soil OM arises from the debris of green plants, animal residues and excreta that are deposited on the surface and mixed to a variable extent with the mineral component (White, 1997). Soil OM is defined as any living or dead plant and animal materials in the soil, and it comprises a wide range of organic species such as humic substances, carbohydrates, proteins, and plant residues (Dudal and Decaers, (1993). Humus is the substance left after soil organisms have modified original organic materials to a rather stable group of decay products as is the colloidal remains of OM (Sopher and Baird, 1982).

Foth (1990) has indicated that the distribution of OM, expressed as organic carbon, is 38% in trees and ground cover, 9% on the forest floor and 53% is in the soil including the roots plus the OM associated with soil particles.

Biological degradation is frequently equated with the depletion of vegetation cover in the soil, but also denotes the reduction of beneficial soil organisms that is an important indicator of soil fertility (Oldman, 1993). Uncultivated soils have higher soil OM (both on surface and in soil) than those soils cultivated years (Miller and Gardiner, 2001). In the forest, there is a continuous growth of plants and additions to the three pools of OM: standing crop, forest floor, and soil. In the grassland ecosystems, much more of the OM is in the soil and much less occurs in the standing plants and grassland floor. Although approximately 50% of the total OM in the forest ecosystems may be in the soil, over 95% may be in the soil where grasses are the dominant vegetation (Foth, 1990). This means unsustainable land management practices, reduces soil fertility, and servely decreases its chemical activity and also its ability to hold plant nutrients (Assefa, 1978). Soluble and exchangeable aluminum in acid soils are substantially reduced by organic amendments (Hoyt and Turner, 1975). Cook and Ellis (1987), Tisdale *et al,* (1995), and Ohare (1997), reported that some of the functions of OM are: (a) Aids in water management as residues or plants protect the soil surface from raindrop impacts, resist wind action, and thus, greatly aid in erosion control. Decomposing OM causes soil aggregation, which helps infiltration and increases pore space in clay soils. Thus, water and oxygen holding capacity are increased, even beyond the absorptive capacity of OM. (b) Increases exchange and buffering capacity since well-decomposed OM or humus has a very high CEC that adds to the buffering capacity of the soil. (c) Minimizes leaching loss because organic substances have the ability to hold substances other than cations against leaching. (d) Sources of nutrients (N, P, S and most micronutrients) and growth promoting substances, that is, hormones or growth -promoting and regulating substances valuable to plants may be produced by organisms that decompose soil OM. (e) Stabilizes soil structure, and (f) Provides energy for microbial activity.

Surface layer is most relevant to assess the impact of management practices on soil OM, because surface soils are easily modified directly by cultivation. The total amount of OC in the soil can be considered as a measure of stored OM. Stored OM reflects the net product or balance between ongoing accumulation and decomposition processes and it is thus greatly influenced by crop management and productivity (Carter *et al.,* 1997).

2.1.4.3 Total nitrogen

Nitrogen (N) is the fourth plant nutrient taken up by plants in greatest quantity next to carbon, oxygen and hydrogen, but it is one of the most deficient elements in the tropics for crop production (Sanchez, 1976). The total N content of a soil is directly associated with its OC content and its amount on cultivated soils is between 0.03% and 0.04% by weight (Mengel and Kirkby, 1987). The N content is lower in continuously and intensively cultivated and `highly weathered soils of the humid and sub humid tropics due to leaching and in highly saline and sodic soils of semi arid and arid regions due to low OM content (Tisdale *et al.*, 1995).

2.1.4.4 Available phosphorus

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils limits the growth of both cultivated and uncultivated plants (Foth and Ellis, 1997). Following N, P has more wide spread influence on both natural and agricultural ecosystems than any other essential elements. In most natural ecosystems, such as forests and grasslands, P uptake by plants is constrained by both the low total quantity of the element in the soil and by very low solubility of the scarce quantity that is present (Brady and Weil, 2002). It is the most commonly plant growth-limiting nutrient in the tropical soils next to water and N (Mesfin, 1996). Erosion tends to transport predominantly the clay and OM fractions of the soil, which are relatively rich in P fractions. Thus, compared to the original soil, eroded sediments are often enriched in P by a ratio of two or more (Brady and Weil 2002). According to Foth and Ellis (1997), natural soil will contain from 50 to over 1,000 mg of total P per kilogram of soil. Of this quantity, about 30 to 50% may be in inorganic form in mineral soils (Foth and Ellis, 1997). The main sources of plant available P are the weathering of soil minerals, the decomposition and mineralization of soil OM and commercial/inorganic fertilizers.

2.1.4.5 Cation exchange capacity

The Cation exchange capacity (CEC) of soils is defined as the capacity of soils to adsorb and exchange cations (Brady and Weil, 2002). Cation exchange capacity is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior. The chemical activity of the soil depends on its CEC. The CEC of a soil is strongly affected by the amount and type of clay, and amount of OM present in the soil (Curtis and Courson, 1981). Both clay and colloidal OM are negatively charged and therefore, can act as anions (Kimmins, 1997).As a result, these two materials, either individually or combined as a clay-humus complex, have the ability to absorb and hold positively charged ions (cations). Soils with large amounts of clay and OM have higher CEC than sandy soils low in OM. In surface horizons of mineral soils, higher OM and clay contents significantly contribute to the CEC, while in the subsoil particularly where Bt horizon exist, more CEC is given by the clay fractions than by OM due to the decline of OM with profile depth (Foth, 1990; Brady and Weil, 2002).

Soil solutions contain dissolved chemicals, and many of these chemicals carry positive charges (cations) or negative charges (anions) (Fisher and Binkley, 2000). Cation exchange is considered to be of greater importance to soil fertility than anion exchange, because plants absorb the majority of essential minerals as cations (Poritchett and Fisher, 1987). The nutrients required for plant growth are present in the soil in a variety of forms (Kimmins, 1997).They may be dissolved in the soil solution, from where they can be utilized directly. They may be absorbed onto exchange sites, from where they enter soil solution or be directly exploited by tree roots or microorganisms that come in contact with the exchange site. Alternatively, they may be firmly fixed in clay lattices, immobilized in decomposition resistant OM, or present in insoluble inorganic compounds. An exchangeable cation is one that is held on a negatively charged surface and displaced by another cation. An exchangeable cation is a desirable form of a nutrient being quickly brought into solution and made accessible to roots by the exchange with proton. Although the cation nutrients held on the exchange sites form a readily available pool, they do not represent the cation supplying ability of the soil (Binkley *et al.*, 1992). Cations removed from the exchange sites often are replenished rapidly from other sources, such as OM decomposition, mineral weathering, or release of ions fixed within the layers of clay minerals. Generally, processes that affect texture (such as clay) and OM due to land use changes also affect CEC of soils.

Therefore, it is necessary to assess the fertility status of soils under mixed and mono-cropping systems in relation to their physical and chemical properties to avoid soil nutrient depletion and degradation, and to sustain production.

2.1.4.6 Exchangeable acidity

Exchangeable hydrogen (H^+) together with exchangeable aluminum (Al^{3+}) are known as soil exchangeable acidity. Soil acidity occurs when acidic H^+ ion occurs in the soil solution to a greater extent and when an acid soluble Al^{3+} reacts with water (hydrolysis) and results in the release of H^+ and hydroxyl Al^{3+} into the soil solution(Rowell, 1994; Brady and Weil, 2002).

As soils become strongly acidic, they may develop sufficient Al^{3+} in the root zone and the amount of exchangeable basic cations decrease. Solubility and availability of some toxic plant nutrient increase and the activities of many soil microorganisms are reduced, resulting in accumulation of OM, reduced mineralization and lower availability of some macronutrients like N, S and P and limitation of growth of most crop plants (Rowell, 1994) and ultimately decline in crop yields and productivity (Miller and Donahue, 1995). Foth and Ellis (1997) stated that during soil acidification, protonation increases the mobilization of Al^{3+} and Al^{3+} forms serve as a sink for the accumulation of H^+. The concentration of the H^+ in soils to cause acidity is pronounced at pH values below four (4) while excess concentration of $Al^{3+}$is observed at pH below 5.5 (Nair and Chamuah, 1993). In strongly acidic conditions of humid regions where rainfall is sufficient to leach exchangeable basic cations, exchangeable Al^{3+} occupies more than approximately 60% of the effective cation exchange capacity, resulting in a toxic level of aluminum in the soil solution (Buol *et al.*, 1989).Generally, the presence of more than one parts per million of Al^{3+}in the soil solution can significantly bring toxicity to plants. Hence, the management of exchangeable Al^{3+} is a primary concern in acid soils.

2.1.4.7 Exchangeable potassium and sodium

Soil parent materials contain potassium (K) mainly in feldspars and micas. As these minerals weather and the K ions released become either exchangeable or exist as adsorbed or as soluble in the solution (Foth and Ellis, 1997). Potassium is the third most important essential element next to N and P that limit plant productivity. Its behavior in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes. Unlike N and P, K causes no off-site environmental problems when it leaves the soil system. It is not toxic and does not cause eutrophication in aquatic systems (Brady and Weil, 2002)

Wakene (2001) reported that the variation in the distribution of K depends on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed. The greater the proportion of clay mineral high in K, the greater will be the potential K availability in soils (Tisdale *et al.*, 1995). Soil K is mostly a mineral form and the daily K needs of plants are little affected by organic associated K, except for exchangeable K adsorbed on OM. Mesfin (1996) described low presence of exchangeable K under acidic soils while Alemayehu (1990) observed low K under intensive cultivation.

Normally, losses of K by leaching appear to be more serious on soils with low activity clays than soils with high- activity clays, and K from fertilizer application move deeply (Foth and Ellis, 1997). Exchangeable sodium (Na) alters soil physical and chemical properties mainly by inducing swelling and dispersion of clay and organic particles resulting in restricting water permeability and air movement and crust formation and nutritional disorders (decrease solubility and availability of calcium (Ca) and magnesium(Mg) ions) (Szabolcs, 1969).

Moreover, it also adversely affects the population, composition and activity of beneficial soil microorganisms directly through its toxicity effects and indirectly by adversely affecting soil physical and as well as chemical properties. In general, high exchangeable Na in soils causes soil toxicity which affects soil fertility and productivity.

2.1.4.8 Exchangeable calcium and magnesium

Soils in areas of moisture scarcity (such as in arid and semi arid regions) have less potential to be affected by leaching of cations than do soils of humid regions (Jordan, 1993). Soils under continuous cultivation, application of acid forming inorganic fertilizers, high exchangeable and extractable Al and low pH are characterized by low contents of Ca and Mg mineral nutrients resulting in Ca and Mg deficiency due to excessive leaching (Dudal and Decaers, 1993).

Exchangeable Mg commonly saturates 5 to 20%of the effective CEC, as compared to the 60 to 90% typical for Ca in neutral to somewhat acid soils (Brady and Weil, 2002). Different crops have different optimum ranges of nutrient requirements. The response to calcium fertilizer is expected from most crops when the exchangeable Ca is less than 0.2

cmol(+)/kg of soils, while 0.5 cmol(+)/kg soil is reported to be the deficiency threshold level for Mg in the tropics (Landon, 1991).

2.1.4.9 Micronutrients (Fe, Mn, Zn and Cu)

The term micronutrients refer to a number of elements that are required by plants in small quantities. This term usually applies to elements that are contained in plant tissues in amounts less than 100 mg/kg (Foth and Ellis, 1997). According to the same authors, the four essential micronutrients that exist as cations in soils unlike to boron and molybdenum are zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn).

Adsorption of micronutrients, either by soil OM or by clay-size inorganic soil components is an important mechanism for removing micronutrients from the soil solution (Foth and Ellis, 1997). Thus, each may be added to the soil's pool of soluble micronutrients by weathering of minerals, by mineralization of OM, or by addition as a soluble salts (Foth and Ellis, 1997). Factors affecting the availability of micronutrients are parent material, soil reaction, soil texture, and soil OM (Brady and Weil, 2002). Tisdale *et al.*, (1995) stated that micronutrients have positive relation with the fine mineral fractions like clay and silt while negative relations with coarser sand particles. This is because their high retention of moisture induces the diffusion of these elements (Tisdale *et al.,* 1995). Soil OM content also significantly affects the availability of micronutrients. According to Hodgson (1963), the presence of OM may promote the availability of certain elements by supplying soluble complexing agents that interfere with their fixation.

Krauskopf, (1972) stated that the main source of micronutrient elements in most soils is the parent material, from which the soil is formed. Iron, Zn, Mn and Cu are somewhat more abundant in basalt. Brady and Weil (2002) indicated that the solubility, availability and plant uptake of micronutrient cations (Cu, Fe, Mn and Zn) are more under acidic conditions (pH of 5.0 to 6.5).

2.2 Cropping systems

Cropping system refers to patterns of crops taken up for a given piece of land, or sequence in which the crops are cultivated on the piece of land after a fixed period and their interaction with farm resources (Balarabe, 2008).

Crop production deals with the production of various crops, which includes food crops, fodder crops, fibre crops, sugar, oil seeds, etc. It includes agronomy, soil science, entomology, pathology, microbiology, etc. The aim is to have better food production and how to control the diseases (Agricultural Act, 1947). Below are some kinds of cropping systems:

2.2.1 Mix cropping

This cropping system entails the growing of two or more crops simultaneously on the same piece of land without any definite row arrangement (Balarabe, 2008). Some of its benefits according to Balarabe (2008) are:

Maintain and enhance soil fertility: some crops are soil exhausting, while others help restore soil fertility. A diversity of crops maintains soil fertility and keeps production levels high.

Enhance crop growth: Crops may provide mutual benefit to each other.

Minimize spread of diseases: The more diverse the species of plants and the longer the period before the soil is reseeded with the same crop, the more likely disease problems will be avoided.

Control weeds: Crops planted at different times of the year have different weed species associated with them. Mixing crops help prevent buildup of any one serious weed species.

Increase soil cover: Growing a diversity of crops helps keep field sizes smaller, which increases soil cover, improves solar radiation capture and reduces erosion.

Use resources more efficiently: Having a diverse group of crops helps to use the available resources effectively. Nutrients, sunlight and water, are evenly shared by plants over the growing period, minimizing the risk for nutrient deficiencies and drought.

Reduce risk for crop failure: Having a diverse group of crops helps prevent total crop failures, as climatic change in one part of the season may not affect all crops equally.

Improve food and financial security: choosing an appropriate and diverse number of crops will lead to a more regular food production throughout the year. With a lower risk for crop failure, there is a greater reliability on food production and income generation.

2.2.2 Multiple cropping

This is the growing of two or more crops on the same field within a given year. Annual and perennial plants can be organized in the same field together. Example is planting rows of fruit trees with cereal grains or vegetables in between and wind breaks planted around the field perimeter (Balarabe, 2008).

2.2.3 Strip cropping

Strip cropping is the presence of two or more crops in the same field, planted in strips such that most plant competition is within each crop rather than between crops. This practice has elements of both intercropping and mono-cropping, with the width of the strips determining the degree of each (Emerson, 2005).

These crops are usually soil conserving and soil depleting crops arranged in alternate strips running perpendicular to the direction of prevailing winds for the purpose of reducing erosion. The crops generally have their main production period at different times of the year. This system uses more water throughout the growing season and ensures some level of productivity during the dry season by the more drought tolerant crop (Balarabe, 2008).

2.2.4 Intercropping

It refers to growing of two or more generally dissimilar crops simultaneously on the same piece of land. Usually, the base crop is grown in a distinct row arrangement. The recommended optimum plant population of the base crop is suitably combined with appropriate additional plant density of the associated crop and there is crop intensification in both time and space dimensions (Balarabe, 2008).

2.2.5 Alley cropping

This is a cropping system in which arable crops are grown in alleys formed by trees or shrubs, established mainly to hasten soil fertility restoration and enhance soil productivity and for shelter (Balarabe, 2008).

2.2.6 Mono cropping

Mono cropping refers to the presence of a single crop in a field. This term is often used to refer to growing the same crop year after year in the same field; this practice is better described as continuous cropping, or continuous mono-cropping. With this kind of cropping system, there is a high degree of nutrient depletion, since there is just a single crop planted, and no alternating crop to help restore soil fertility, and subsequently lower levels of crop production (Balarabe, 2008). This single crop gets no mutual benefit since it's just alone and this increases the spread of diseases. The probability of having crop failure is very high, due to susceptibility to diseases and a change in climate which might not favor the growth of the crop (Balarabe, 2008).

2.2.7 Double-cropping

Also known as sequential cropping is the practice of planting a second crop immediately following the harvest of a first crop, thus harvesting two crops from the same field in one year. It requires a season long enough and crops that mature quickly enough to allow two harvests in one year (Emerson, 2005).

2.2.8 Relay intercropping

It is a technique in which different crops are planted at different times in the same field, and both (or all) crops spend at least part of their season growing together in the field. An example would be dropping cover-crop seed into a soybean crop before it is mature (Emerson, 2005).

This research was how ever focused on mono and mix cropping systems, because these were the cropping systems practiced by farmers in Santa sub-division.

2.3 Sustainable farming practices that enhances soil fertility.

Until the industrial revolution of the early to mid 1900's, farming practices were relatively environmentally friendly. Traditional farms were small-scale, used biological controls of pests and diseases, used crop rotation to maintain soil nutrients, included buffer zones at field edges, and involved little or no heavy machinery. The modernization of farming practices around the 1950’s resulted in extreme increases in productivity often to the detriment of environmental quality (Gliessman, 1998).

Sustainable/conservable farming is farming that limits the use of synthetic fertilizers or pesticides, employ farm-produced resources and cultural management, raise more diverse crops and livestock, and express commitment to environmental sustainability (Gliessman, 1998). Its goal is long-term agricultural sustainability and profitability for the farmer (Draeger, 1990). Sustainable agriculture was first introduced in the United States around 1911, but industrialization along with government subsidies encouraged farmers to use conventional agricultural methods (Reganold et al., 1990). However, recent concerns about the environmental and economic impacts of conventional farming are encouraging farmers to adopt more traditional practices. Traditional methods are considered more sustainable because they: (1) maximize yield without exploiting the environment; (2) depend on local conditions and resources instead of using external inputs to attempt to control the environment; (3) emphasize nutrient recycling and minimizing negative impacts on the environment; and (4) maintain diversity (Gliessman, 1998).The goals of sustainable agriculture

- Minimize negative impacts to the environment and eliminate release of harmful substances into the atmosphere, surface or ground waters.
- Maintain and improve soil condition and prevent soil erosion.
- Use water in a responsible manner to recharge aquifers and meet the needs of the environment and people.
- Replace external inputs with nutrient cycling, improved conservation, and better education.
- Preserve biological diversity, both in wild and domestic landscapes

Source (Gliessman, 1998).

The effects of declining soil fertility on yield growth are particularly visible in Africa, where the most serious food security challenges exist (Badiane and Delgado 1995). The high level and inappropriate use of chemical fertilizers, decline in soil organic matter, and insufficient attention to crop nutrient studies contribute the most to the loss of soil fertility in the region (Kumwenda *et al.*, 1996).

Modern, or conventional agricultural practices use intensive tillage, monoculture (mono-cropping), irrigation, application of inorganic fertilizers and chemical pest control (Gliessman, 1998). These practices greatly increased crop yields, and agricultural production rose steadily after World War II. These conventional agricultural practices, however, have numerous long-term ecological impacts such as soil degradation, decline in soil fertility, habitat alteration (clearing land for agriculture causes fragmentation), water quality impacts, species composition impacts, and adverse effects of irrigation. Negative impacts on the environment can be minimized by replacing the use of synthetic pesticides and fertilizers with ecologically sound management practices such as integrated pest management, nutrient management, irrigation water management, animal waste management, and tillage management (ERS 1997, Gliessman, 1998).

Modern agriculture is highly dependent on external inputs for materials, energy, and technology. Continued dependence on these inputs leaves farmers susceptible to shortages, market fluctuations, and price increases (Gliessman, 1998). Sustainable farming strives to limit the dependence on external inputs. Biological controls replace synthetic mass-produced pesticides, crop residue management and animal waste management replace the use of fossil fuel based fertilizers, and crop rotation replaces monoculture cropping which is often highly dependent on commercial seed producers. Also, by removing dependence on external inputs, farmers practicing sustainable farming focus more on local conditions, local ecosystems, and locally-adapted crop plants as well as maintain experience-based knowledge and connection with the land (Gliessman, 1998).

The process of reversing soil degradation is expensive and time-consuming. Farmers must find a way of being competitive and profitable while protecting environmental quality and investing in the natural resource base upon which their enterprise and the local economy depend on. Good management can limit physical losses. Good management includes use of cover crops and soil conservation measures; addition of organic matter to the soil; and judicious use of chemical fertilizers, pesticides, and farm machinery.

Organic matter content is important for the proper management of soil fertility. Organic matter in soil helps plants grow by improving water-holding capacity and drought-resistance. Moreover, organic matter permits better aeration, enhances the absorption and release of nutrients, and makes the soil less susceptible to leaching and erosion (Sekhon and Meelu, 1994). Soil organic matter plays an important part in establishing the intrinsic properties of a soil, which make plant growth possible. Soil organic matter helps sustain soil fertility by improving retention of mineral nutrients, increasing the water-holding capacity of soils, and increasing the amount of soil flora and fauna (Woomer *et al.,* 1994). Continuous cropping and erosion reduce the level of soil organic matter. Low-input systems can maintain and enhance soil organic matter through crop rotation and intercropping, the application of animal and green manures, fallowing, and reduced tillage (Kumwenda *et al.,* 1996). Some of these sustainable farming practices that enhance soil fertility include:

Zero or reduce tillage

Zero tillage is an important conservable farming practice derived from experience in Brazil with so-called ‘ZT sustainable agriculture’. Zero tillage is an important component of conservable agriculture (CA). This conservation tillage aims to leave crop residues on the surface that minimizes soil erosion and adds to soil organic matter content (Hobbs & Gupta, 2002). The potential gains from conservation or reduced tillage lie not only in conserving but also in enhancing the natural resources (e.g., increasing soil organic matter) without sacrificing yields. This practice makes it possible for fields to act as a sink for carbon, increase the soils’ water retention capacities and decrease soil erosion, and cuts production costs by reducing time and labor requirements, as well as mechanized farming cost (FAO, 2008).This ability to address a broad set of farming constraints makes conservation tillage a desirable (and widely adopted) component of sustainable farming (Lee, 2005). No or reduce tillage slows down the rate and extent of long-term declines in soil organic matter. This system build soil organic matter over a period of years and reach a higher “steady state” level than tilled systems.

Moreover, the water-retention characteristics of conservation tillage make it especially appealing in water-deficient farming areas (Twarog, 2006). In addition to reducing natural risks, conservation tillage enables poor farmers to avoid the financial risk of purchasing chemical fertilizer on credit.

Permanent soil cover

Use cover crops and green/animal manure to build soil quality and fertility. Cover crops produce high biomass, which adds to soil organic matter and increases nutrient availability. Temperature, moisture conditions, placement of the residue and quality of the cover crops influence nutrient release. Cover crops improve the soil’s physical and chemical properties with carbon and nitrogen cycling. Some cover crops actually suppress certain parasitic nematodes and soil borne diseases. Cover crops have superb weed suppressing effects by competing with weeds for light. Residue cover protects the soil from wind and water erosion (Hobbs & Gupta, 2002).

Crop rotation

Rotate crops to enhance yields and facilitate pest management. Crops are changed in the field from year to year according to a planned sequence rather than the same crop being grown in the same field. The crop rotation can include both annual and perennial crops which are seeded for several years (Hobbs & Gupta, 2002). Crop rotation break weed and pest cycles, and provides complementary fertilization to crops in sequence with each other, i.e. legume crops preceding corn or tomatoes. Prevent buildup of pest insects and weeds. In some cases, yield increases follow from the “rotation effect.” Ideal rotation includes planning over the long term with fields in rotation of crops, cover crops and livestock. Rotate crops to maximize use of nutrient inputs and distribute nutrient demand placed on soil (Hobbs & Gupta, 2002).

Integrate crop and livestock production

Skillfully using livestock to harvest forages leads to improved soil fertility, diverse, dense, and useful pasture ecology, and an extended grazing season. Fertile soil and productive pastures, in turn, support healthy animals. In a system of controlled rotations, pastures are subdivided into paddocks – fenced acreage of any given size. Livestock is moved between paddocks at frequent intervals, giving animal’s access to a limited pasture area over a short period. As a result, the plants have time to recover, the roots maintain energy reserves, and the livestock always have high-quality forage. A primary strategy of controlled grazing is to use fencing and livestock movement as tools to manage forage growth and protect it from overgrazing (Hobbs & Gupta, 2002).

Use of compost

Use of compost in crop production is beneficial to build soil organic matter, add nutrients to the soil and retain water. Nutrient contribution of manure-based compost is balanced between N-P-K. Have a compost nutrient assessment done. How much compost to apply and timing is different on each farm (Hobbs & Gupta, 2002). Thoroughly compost all imported animal manure to insure destruction of viable weed seed (Hobbs & Gupta, 2002).

Use of manure

The use of fresh or un-decomposed manure in agricultural systems is of great benefit to the farm. Integrate grazing animals or other livestock onto your farm to produce compost for your farms (Hobbs & Gupta, 2002).

2.4 Theoretical Framework

2.4.1 The concept of ecological footprint.

It represents the human impact on the Earth in a clear manner. As its originators (Mathis and William, 1990) note, the ecological footprint calculations have reinforced the view that if everyone enjoyed a North American standard of living then globally this would require three earths— although finding two other planets would be difficult (Wackernagel and Rees, 1996). Simply stated, we are living beyond our biophysical means. The ecological footprint is one attempt at developing a biophysically-based ecological economics, which approximates reality better than many economic expansionist models.

The ecological footprint merely shows that current human development is unsustainable. We only have one Earth (Ward and Dubos, 1972). If we are to engage actively in the processes of making development sustainable, we need to establish indicators so that we know if we are moving towards or away from a sustainable future. We also need to consider which trajectories are equitable, economically and ecologically desirable and achievable. There are plethora of indicators attempting to capture the economic, environmental and social aspects of sustainable development (Moffat, 1996; Hanley *et al.,* 1999).

From ecological footprint arguments, some of the Earth's ecosystems should be set aside (like some form of safe minimum standard). Determining such a minimum amount of the ecosystem is difficult. Then a set of different trajectories of unsustainable and sustainable development could be 'forecast' using dynamic modeling and GIS (Moffatt, 1996; Moffatt *et al.,* 2000).

Ecological Footprint being a measure of the amount of bio-productive land and water required to support a person's lifestyle, includes the land needed to grow their food, dispose of their waste and absorb their carbon emissions. The footprint counts all the impacts of personal spending as well as the business and government expenditure on their behalf.

According to Wackernagel (2002) the Ecological Footprint concept is based on the following basic assumptions;

- The majority of the resources people or activities consume and the wastes they generate can be tracked.
- Most of these resources and waste flows can be measured in terms of the biologically productive area necessary to maintain them. Resource and waste flows that cannot be measured in terms of biologically productive area are excluded from the assessment

- By scaling each area in proportion to its bio-productivity, different types of areas can be converted into the common unit of average bio-productivity, the global hectare. This unit is used to express both Footprint and bio-capacity
- Global hectares represent aggregate demand or ecological footprint and therefore, each hectare of productive area can be scaled according to its bio-productivity and then added up to calculate bio-capacity.
- As the ecological footprint is expressed in global hectares, human demand can be directly compared to global, regional, national, or local bio-capacity.
- Area demanded can exceed the area available. If demand on a particular ecosystem exceeds that ecosystem's regenerative capacity, then the ecological assets are being diminished. For example, people can temporarily demand resources from forests or fisheries faster than they can be renewed, but the consequences will be a gradual reduction of stocks in that ecosystem. When the human demand exceeds available bio-capacity, this is referred to as an overshoot.

2.4.2 Advantages of the ecological footprint concept.

There are several advantages and limitations associated with the development of the ecological footprint concept.

The major advantages of the ecological footprint It gives a clear, unambiguous message often in an easily digested form. The clarity of the message is an important function of any indicator for both policy makers and the general public:

- The calculation upon which the ecological footprint is based is relatively easy to undertake and much of the data is available at different spatial scales.
- Calculations do include trade within the ecological footprint. If world trade were included then, under the assumption of all areas maintaining their inhabitants' standards of living, there would be some losers as well as winners. A glance at the Human Development Index gives some empirical support of the increasing numbers of poor within the Third World as well as pockets of poor and a growing underclass in rich Western democracies.
- The measure is simply stated as a stock, for example, x units of land per capita. It is obvious that each areal unit can also supply a flow of goods, information, natural and manmade capital as well as pollution into and out of the region.
- Source: (Moffatt, 1996; McLaren *et al.*, 1998).

2.4.3 Limitations of the ecological footprint concept.

It is clear that the simple statement of the ecological footprint is not in itself anything more than an important attention grabbing device. Below are some of the limitations of the ecological footprint concept:

- The ecological footprint is a static measure. It is possible to examine the dynamics of this measure by re-course to viewing the ecological footprint through historical time. Such historical studies may unearth the processes leading to unsustainable practices at different spatial scales (Moffatt, 1996; Lange, 1999).
- As in many studies of sustainability, the role of technological change is ignored, but it would be worth exploring. Presumably, the ecological footprint could be substantially reduced by several practices. These would include using environmentally friendly technologies, using current technologies more efficiently or reducing the throughput of resources.
- The ecological footprint does not consider the oceans and underground resources including water.
- The ecological footprint represents a stock measure. It would be useful to integrate the stock measure with the flows into or out of an area. The use of material flows or integrated economic and environmental accounting (United Nations, 1990) linked to a dynamic model of sustainable development would help.
- It offers no policy suggestions apart from either including more land, reducing population, or reducing consumption per head. The policy instruments required to achieve such desirable goals are not stated.

2.4.5 Application of the ecological foot print theory to the research.

Fifty years ago there were fewer than half as many people as there are today. They were not as wealthy and the pressure they inflicted on the environment was lower. The widely held view then was that global development would necessarily involve increased exploitation of environmental resources, in particular, land and water. Since then population growth and dietary change have driven up demand for food and other agricultural products and in the next 50 years, global food and feed crop demand is expected to double (Greenland *et al.,* 1998; Rosegrant *et al.,* 2002; Brown, 2004; CAWMA, 2007).

Over 85% of the rural population of Sub Saharan Africa continues to rely on agriculture for their survival (Mahendra *et al.,* 2008).Rates of agricultural expansion are decreasing globally but still expanding in Sub Saharan Africa (SSA). This is attributed to unsustainable farming practices leading to land degradation and subsequently a decline in the soil's fertility status, thus influencing farmers to cut more of the forest areas in search for suitable land (fertile land). It is estimated that 70% of the grasslands, 50% of the savanna, 45% of the temperate deciduous forests and 27% of the tropical forests have been cleared for agriculture (Foley *et al.,* 2011).

More land is needed for agriculture to meet the food demands of individuals, from a limited natural capital stock every year. Therefore, the tendency for an increasing ecological footprint is obvious. A declining bio-productive land, on which an increasing population depends on for resources, is already an indication of danger.

Villages in Santa sub-division mostly depend on agriculture for their livelihood with the high reliance of these inhabitants on agriculture for sustenance; their well-being is being ensured to a greater extend by these cropping practices. On the other hand, there is an ecological footprint that is being left on the environment, especially with the unsustainable farming practices and unsustainable measures taken to improve soil fertility, especially the inappropriate use of chemical/inorganic fertilizers. Very little is done by the farmers to manage the natural stock and enhance the regeneration capacity of the existing agricultural land, in order to reverse the degrading land to a more conservable one that ensures sustainable agricultural productivity for the future generation. The unsustainable farming practices and measures taken to improve the productiveness of the agricultural land, has been an ecological overshoot, resulting to low regenerative capacity of these agricultural land. This no doubts leads to loss of the natural capital stock, which could result to loss in ecosystem services.

Rees and Wackernagel seem to be having the same view with Robert Thomas Malthus, that 'if humanity continues to harvest its resources in these unsustainable manners, then the end result will be a case of humanity sur-passing the carrying capacity of the bio-productive resources on which they depend for their livelihood.

In the course of applying this ecological footprint theory, the researcher came up with this tree diagram.

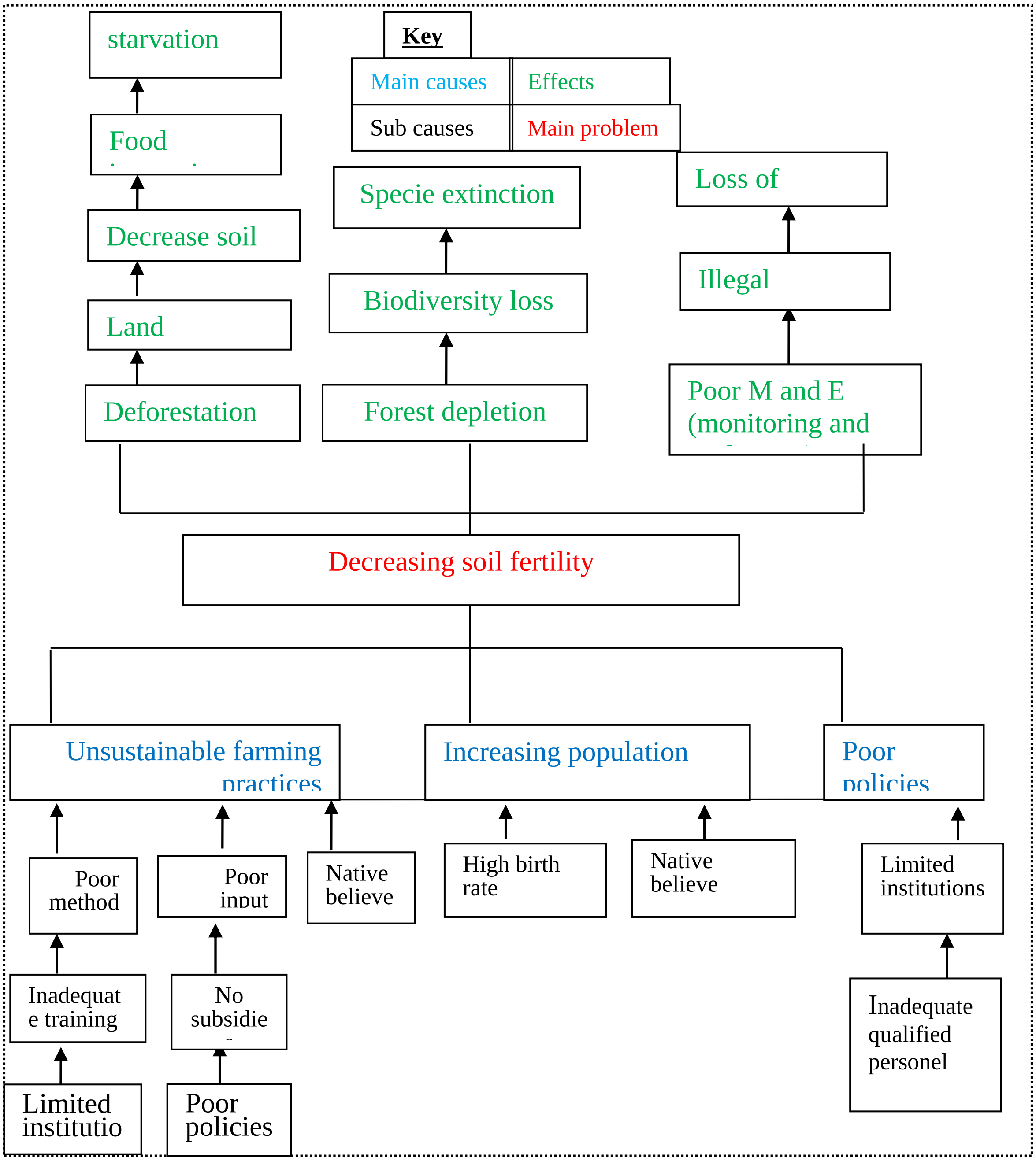


Figure 2 4: Application of the ecological footprint theory to decreasing soil fertility

Therefore the ecological footprint is one contribution to the overall goal of making human development sustainable for current and future generations living in harmony with the rest of the biosphere.

2.4. 6 Gaps identified in the literature

So many researches as seen from literature have been carried out that talk of unsustainable farming practices contributing greatly to reduction in soil fertility. But very little has been done on cropping systems and soil fertility. Assessing soil fertility status under mixed and mono-cropping systems would be a better way of characterizing soil under different cropping systems. This would be a significant way of proposing sustainable farming practices under these cropping systems, and will thus be a more sustainable means of improving soil nutrients that enhance soil fertility, necessary for plant growth.

Assessing soil fertility status under mixed and mono cropping systems would enable one to easily identify unsustainable farming practices carried out in the different cropping systems that decrease soil fertility, and thus be able to propose better measures under the different cropping systems. Proposing sustainable measures on how both cropping systems should be carried out that influences soil fertility will be a good means of preserving natural resources (increasing soil fertility and thus preventing land degradation, to ensure ecosystem production and recycling services) and increasing crop productions to ensure food security, without jeopardizing conservation efforts.

More needs to be known about whether constraints arising from a shortage of organic matter, low pH level, low water availability, high bulk densities, low porosity, decrease nitrogen and phosphorus, etc is as a result of which cropping systems coupled with poor farming practices, affecting crop production in potentially rich soils, as a result of not knowing which crops to inter mix or which crop to rotate following a previous crop planted, on the same piece of land for a period of time.

Therefore, deriving information on the fertility status of soils under mixed and mono-cropping systems requires ongoing researches, as well as the initiation of new and sustainable researches, and monitoring efforts specifically intended to learn more about soil management under different cropping practices. A conservable research like this, could lead to the development and greater integration of knowledge that provide farmers with a stronger incentive to improve yields, maintain soil fertility, and thus sustain agriculture without sacrificing soil productivity of the future generation.

Therefore tackling the soil fertility decline issue and favoring the investment into soil fertility is fundamental to achieve the Millennium Development Goals of reducing extreme poverty and hunger by increasing the total food production (Goal 1) and ensuring environmental sustainability by intensifying sustainable agricultural production (Goal 7) in SSA (Verchot *et al.*, 2007; Place *et al.*, 2003).

CHAPTER THREE

METHODOLOGY OF THE STUDY

3.1 Model specification

The primary focus of the study was to compare changes in soil quality under mixed and mono-cropping systems. In comparing changes in soil quality under mixed and mono-cropping systems, certain parameters were used to compare the soil quality of soils under these cropping systems in Santa sub-division. Parameters that were used in comparing soil quality between the two cropping systems included soils physical and chemical properties. Under physical properties, the study looked at texture, bulk density, and porosity. For chemical properties, the study looked at pH, cation exchange capacity (CEC), available phosphorus, total nitrogen, exchangeable acidity, exchangeable bases(Ca, Mg, K, and Na), and organic matter (OM). These properties were used to compare soil fertility status between farms under mix and mono-cropping systems since the properties mentioned above are the main determinant of soil fertility.

$FI = P_l + BD_l + CEC_l + pH_l + OM_l + N_l + Por_l + EA_l + EC_l$

Where FI = fertility index

P_l= Level of phosphorus

BD_l= Level of bulk density

CEC_l= Level of cation exchange capacity

pH_l = pH level

OM_l= Level of organic matter

N_l = Level of nitrogen

Por_l = Total porosity level

EA_l = Level of exchangeable acidity

EC_l= Level of exchangeable cations

Where fertility index

Table 3.1: Fertility index and rating

Rating	Fertility Index (FI)
Very low	0-50
Low	50-75
Medium	75-100
Very high	150-300
Extremely high	300+

Source: Beernaert and Bitondo, (1992).

Table 3.2: Critical values of nutrient and soil properties

Properties	Critical values				
	Very low	Low	Medium	High	Very high
OM %	<1	1-2	2-4.2	4.2-6	>6
Total N g/Kg	< 0.5	0.5-1.25	1.25-2.25	2.25-3.0	>3.0
C/N	<10 = good, 10-14 = medium and >14 = poor				
Ca cmol/kg	<2	2-5	5-10	10-20	>20
Mg cmol/kg	<0.5	0.5-1.5	1.5-3	3-8	>8
K cmol/kg	<0.1	0.1-0.3	0.3-0.6	0.6-1.2	>1.2
Na cmol/kg	<0.1	0.1-0.3	0.3-0.7	0.7-2.0	>2
Bray 2–P mg/kg	<7	< 7-16	16-46	>46	
pH	5.3- 6.0 = moderately acid, 6.0-7.0 = slightly acid, 7.0-8.5 moderately alkaline				
CEC_7 cmol/kg	0-20	21-40	41-60	61-80	81-100

Source: Beernaert and Bitondo, (1992).

The study further identified farm management measures that were taken by farmers practicing these cropping systems. Also, weaknesses of these strategies were equally identified. Comparisms were made on the fertility status of soils under mono-cropping and that under mixed cropping systems using the determinants of soil fertility. These comparisms were expressed mostly in words and tables based on laboratory routine analysis results, SPSS, and Excel analysis. Based on the determinants of soil fertility and with relevant results obtained from the field, sustainable recommendations were made. The experimental design below summarizes the whole study.

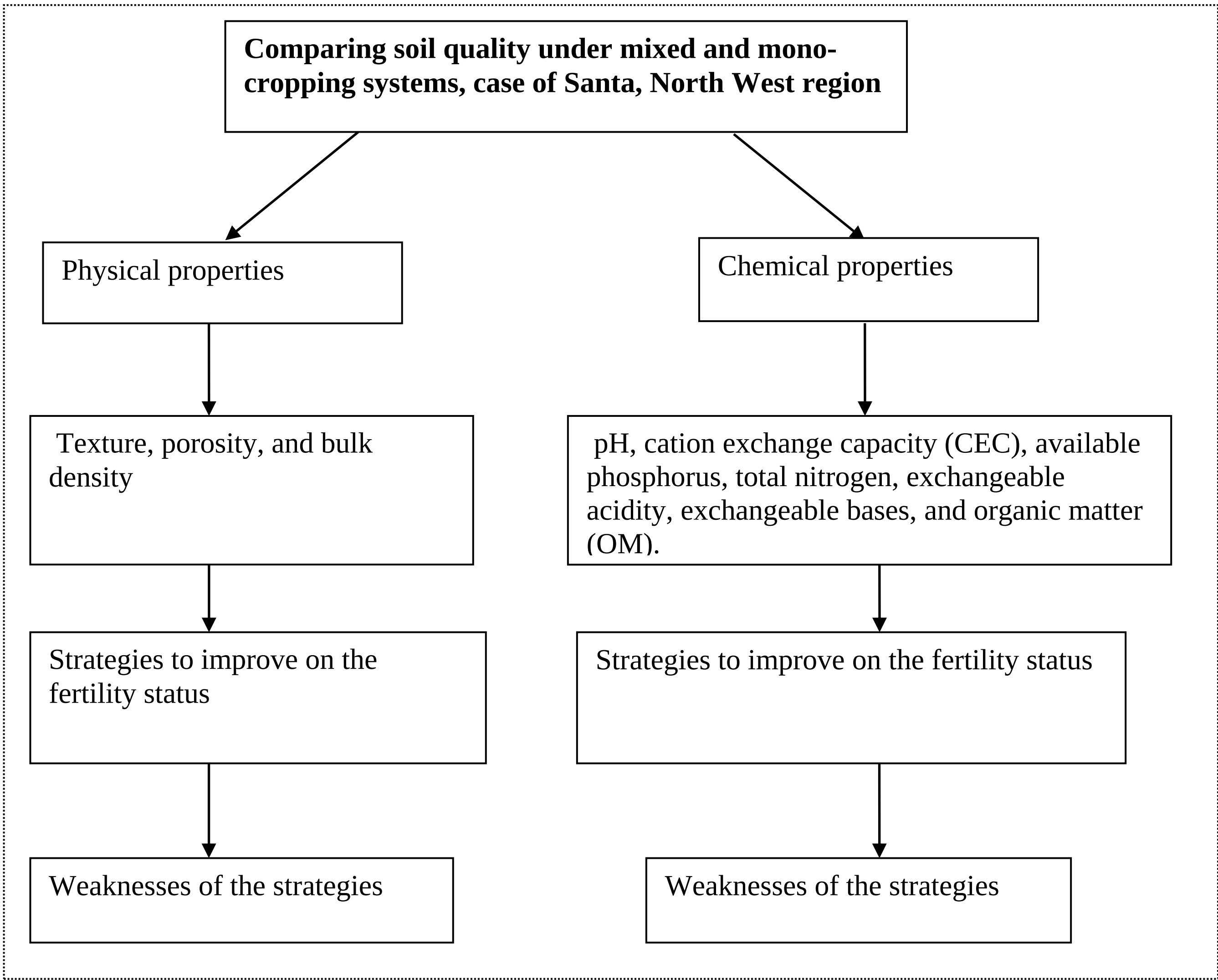


Figure 3 .1: Experimental design on comparing soil quality under mixed and mono-cropping systems in Santa sub-division.

3.2 Description of variables

Variables for the study included the physical and chemical characteristics of soil.

For the physical we had:

Soil bulk density: Bulk density was determined by the undisturbed core sampling method after drying the soil samples in an oven at 105^0c to constant weight (Black, 1965).

Soil texture: Soil texture was determined using the soil texture triangle, comparing percentages of the various particle size, that is clay, sand and silt to give conclusions on soil types under mono and mixed cropping systems in Santa sub-division.

Soil porosity (percentage pore space): This was computed from the values of bulk density (BD) and particle density (Brady and Weil, 2002) as;

$$\text{Total pore space (\%)} = (1 - BD/PD) \times 100$$

For chemical properties we had:

Soil pH and electrical conductivity: pH of the soils were measured using the electrometric method, pH meter (black, 1965).

Organic matter: The wet oxidation method was used (black, 1965). This method measured the active or decomposable organic matter in the soil. The carbon in plant residues and humus was oxidized.

Cation exchange capacity: Cation exchange capacity was determined by saturation of an exchangeable complex with a given cation and then later on determined the total amount of the absorbed cations (black, 1965).

Exchangeable acidity: This was determined using the $BaCl_2$-TEA (total exchangeable acidity) method. Collected soil samples were leached with a solution consisting of $BaCl_2$and triethanolamine, neutralized with HCL to pH 8(black, 1965).

Total nitrogen: The kjeldahl analytical method was used to measure the amount of organic plus ammonium and nitrogen present. In this method, the organic and ammonium forms of nitrogen were converted to $(NH_4)_2SO_4$ by digestion with concentrated sulphuric acid. Ammonium was liberated from the $(NH_4)_2SO_4$by the addition of sodium hydroxide solution. The ammonium was collected in a boric acid solution and then titrated directly with a strong acid (black, 1965).

Available phosphorus: The amount of phosphorus in the collected samples was obtained by using the Bray and Kurtz extractants (Bray P_1) 0.03N NH_4F + 0.025N HCL (Bray and Kurtz, 1945). A ratio of 1:5 was used, since the ratio of soil extractant affects the amount of phosphorus extracted.

3.3 Data collection

Data for the study employed both primary and secondary data.

Primary data was obtained using structured questions to farmers of the four selected villages in Santa sub-division, which included Akum, Mbei, Pinyin, and Njong. Purposive sampling method was used as sampling method of the study population since the study was geared towards farmers practicing mixed and mono-cropping systems. A total of one hundred and seventeen structured questionnaires were administered in the four selected villages out of the nine villages in this area. The researcher had to administer 120 questionnaires with 30 being administered in each of the four villages, but in the course of administering the questionnaires, 27 was administered in one of the villages instead of 30 due to unfavorable weather conditions at the time of administering the questionnaires. Of the 117 questionnaires, 27 were administered in Mbei village while 30 questionnaires each were administered in the other three villages. These questionnaires were administered randomly in the houses of farmers in the selected villages. Names of farmers were taken; this was done to avoid collection of the same data on different questionnaires from the same individuals coming from the same household.

The nine villages in this sub-division included Mbei, Njong, Akum, Mbu (Baforchu), Alatening, Baba, Awing, Baligham and Pinyin. The four villages where this study was carried out included: Akum, Njong, Pinyin, and Mbei. Purposive sampling was used in the selection of these villages, because pre-field studies indicate that these villages are more involved in intensive farming as compared to the other five villages and there is a high degree of homogeneity regarding farming practices. Therefore the views that were expounded by the four purposively selected villages represented the views of farmers in the other five villages in Santa sub-division. Field observations were made in the course of administering the questionnaires to the farmers on the various measures of farming in preparing their farms for cultivation.

Twenty (20) soil samples from major farming areas based on the sizes of the farms from $500m^2$ to one hectare (Ha) and cultivation history (at least 5 years) were collected on level farms, to avoid bias in the results. Collection of the samples was randomly done, with ten samples collected from mixed cropping farms, and ten samples collected from mono-cropping farms.

A necessary assumption that was made in this research was that soil conditions or parameters for all the sites were similar before changes in the cropping and farming practices were introduced. Because any differences before mixed and mono-cropping practices were introduced, should have been small and associated with lateral movement of soil materials on the sites where soil samples were collected. The observed differences in present soil conditions or other parameters were assumed as being caused by the present cropping and farming practices.

The collection of soil samples under mono-cropping farms were as follows:

Two samples from Irish potatoes farm from Njong village, two from cabbage farm from Mbei, two from tomatoe farm from Pinyin, two from huckleberry farm from Mbei village, and two from cabbage farm from Mbei village. This made a total of ten (10) soil samples that were collected from mono-cropping farms. No sample was collected for maize and beans, because no maize and beans mono-cropping farms were found during the study.

Ten samples were equally collected from farms where mixed-cropping was practiced; the collection was as follows:

Three from a farm that had a combination of maize, beans, Irish and sweet potatoes, cocoayams, yams, green spices, from Njong village, three from a farm having a combination of same crops listed above from Pinyin village and four from Akum village.

All samples were collected on level land to avoid bias in the results. This, therefore, made a total of twenty (20) soil samples from both mono-cropping and mixed-cropping farms that were collected. These crops were chosen because they were the most common annual crops grown in the study area with short growing cycles. These twenty soil samples were preserved in twenty different plastic bags, and each carried its label. These samples were collected from depths of 0-20cm each using a soil augar. This was because there was considerable heterogeneity in soil properties at the spatial scale of a few meters or less, and this was particularly so for soil parameters like soil OM content which is driven by litter inputs. During the collection of these soil samples, dead plants, furrow, old manures, areas near trees and compost pits were excluded. This was done to minimize differences, which could arise because of the dilution of soil organic matter due to mixing through cultivation and other factors. Separate soil core samples from the 0-20 cm depths were taken with open sharp-edged plastic cylinders forced manually into the soil and wrapped with aluminum foil for bulk density determination. Global positioning system (GPS) was used to identify the geographical locations of the sampling sites respectively. These samples were air-dried for a period of four (4) days. The air- dried samples were later on taken to the soil science research laboratory of the University of Dschang. The air-dried soil samples were ground to pass through a 2-mm mesh sieve and following standard methods, physical and chemical characteristics of the samples were determined.

Secondary data constituted review of literature on soils, soil profile, chemical and physical characteristics of soils, cropping systems, and sustainable farming practices that enhance soil fertility.

3.4 Analytical approach

A general visual field survey of the area was carried out given a general view of the variations in the study area. Both qualitative and quantitative techniques were used for data analysis. Analysis of data made use of an integrated approach assuming form of tables, maps, percentages, and histograms. A routine soil analysis was done. Soil physical and chemical analyzes were carried out at the science research laboratory at the University of Dschang. Standard laboratory procedures were followed in the analysis of the selected physical, and chemical properties considered in this study. Questionnaire data was analyzed using SPSS 20 (statistical package for social sciences version 20) and Microsoft Excel 2007. Maps and areas where soil samples were collected were produced using ArcGis10.1. Analysis of variance was done to compare the differences between the means of the physical and chemical characteristics of soils under mixed and mono-cropping systems.

3.5 Validation of results

Results were validated based on laboratory and questionnaire analysis on the variations of soil physical and chemical property between mono-cropping and mixed-cropping systems. Results were generalized. This was based on the findings and results of variation in soil's physical and chemical properties of both cropping systems, which were mono-cropping and mixed cropping systems. Also, the views that were expounded by the four purposively selected villages represented the views of farmers in the other five villages. Conclusions on soil fertility status under mono-cropping and mixed cropping systems in Santa sub-division, North West region of Cameroon, were drawn using ANOVA.

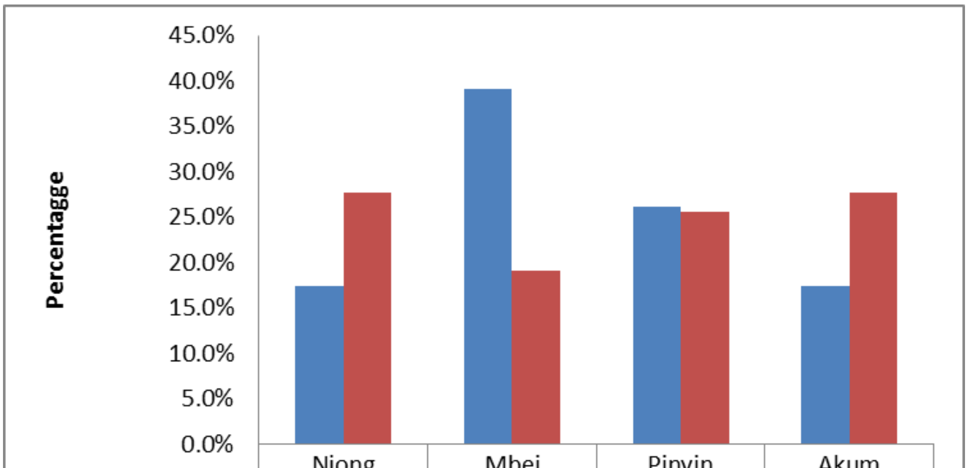
CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

4.1 Demographic, Crop production and Productivity Information

4.1.1 Demographic Information

Four out of the nine villages of Santa sub-division were sampled, and the views of these four villages expounded the views of farmers in the other five villages (Awing, Alatening, Baforchu, Baba and Baligham). Figure 4.1 below shows the distribution of cropping systems practiced by the farmers in the villages under the study area. Majority (39.1 %) of those who practiced mono-cropping were from Mbei village while the majority (27.7 %) of those who practiced mixed cropping came from Akum and Njong village.



	Njong	Mbei	Pinyin	Akum
Mono Cropping	17.4%	39.1%	26.1%	17.4%
Mixed Cropping	27.7%	19.1%	25.5%	27.7%

Figure 4.1: distribution of cropping systems practiced in the study area

The different ages (fig 4.2) ranged from <20 to >50 years. Majority of the population (over 60 %) had an age range between 20 to 35 years and most of them practiced mono-cropping system, and the least were those less than 20 years who mostly practiced mixed cropping system. This could be attributed to the fact that most of those of ages between 20 and 35 are the active group, and still has a lot of energy to carryout farming.

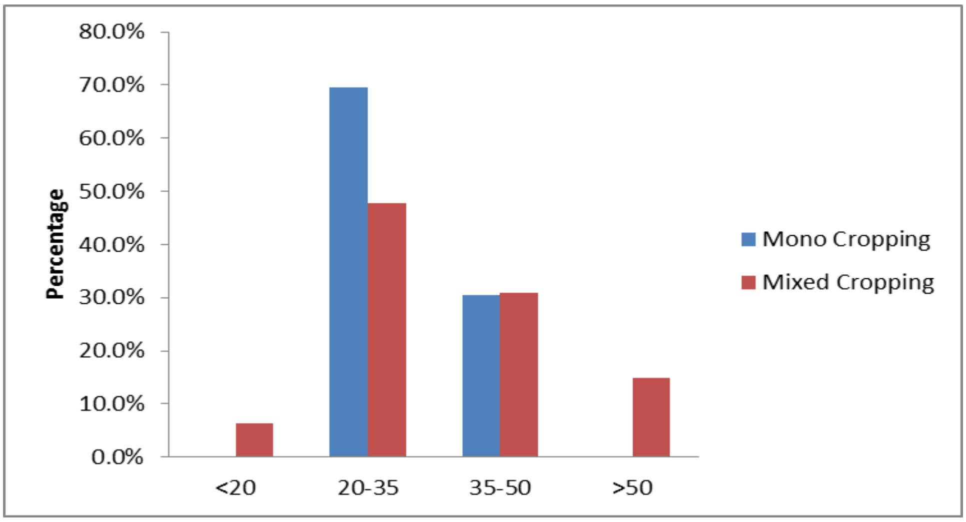


Figure 4.2: Age distribution of farmers who practiced mixed and mono-cropping system

The population of the men was greater than that of the women, as shown in fig 4.3. With the men given a percentage of over 60, who mostly carried out mono-cropping system and just a few of them practiced mixed cropping. On the other hand, the number of women was lower than that of the men and mostly carried out mix cropping. This is attributed to the fact that the women are into some other kind of activities, such as business, tailoring, hair dressing, etc.

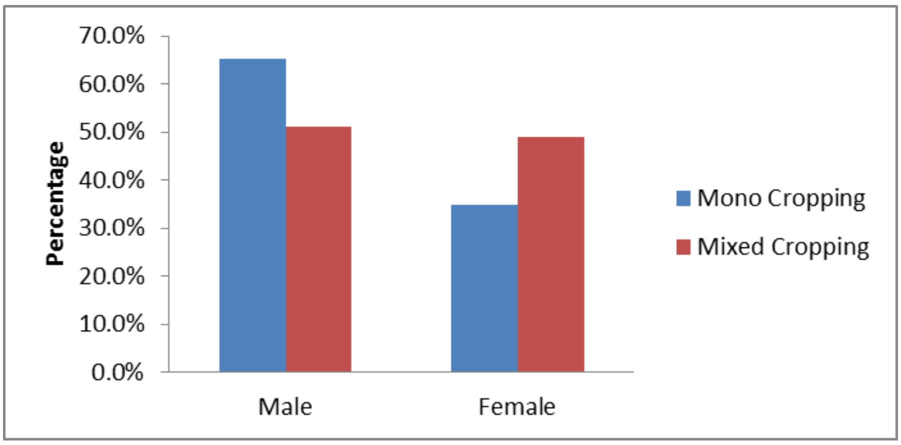


Figure 4.3: Gender distribution of farmers who practiced both cropping systems

Most of the farmers (70 %) who carried out mixed cropping were married, and those who practiced mono-cropping and were married were about 55 %. Few of them were single and little were either widows/ers (Fig 4.4)

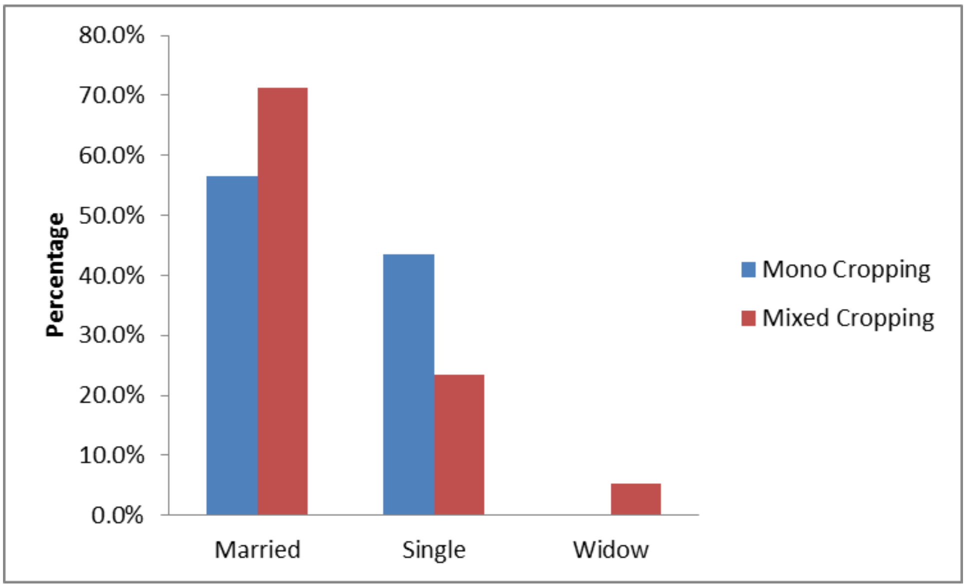


Figure 4. 4: Marital status of farmers

Most of those who practiced mixed cropping had as educational qualification primary level with a total of 59.6 % while 47.8 % of those who practiced mono-cropping had as qualification primary education since most didn't have the financial means to further their education (fig 4.5). For both cropping systems, few had as qualification university degree and professional qualification.

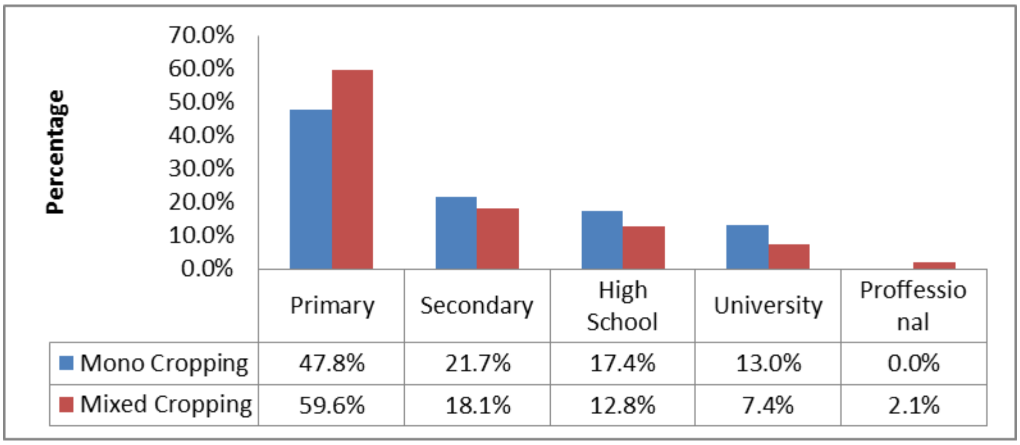


Figure 4.5: Educational level of farmer

4.1.2 Crop production information

80.3 % of the farmers practiced mixed cropping while 19.7 % practiced mono-cropping (fig 4.6)

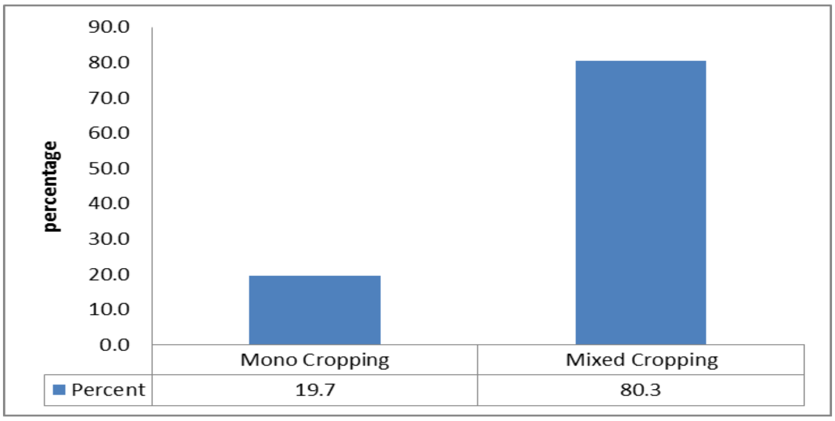


Figure 4. 6: Type of cropping system practiced by farmers in Santa

82.6 % of the farmers who practiced mono-cropping and 29.8 % of those who carried out mixed cropping gave as reason for practicing the cropping system high productivity. That of those who carried out mono-cropping is greater than those who practiced mixed cropping, because those who carried out mono-cropping are business oriented. 45.7 % of those who practiced mixed cropping gave as reason for doing such cropping system because it was less expensive for them, little farm inputs but average crop productivity. 14.9 % of those who carried out mixed cropping and 4.3 % of those who practiced mono-cropping gave as reason for practicing such cropping systems as their culture, they grew up and saw their parents doing such cropping system and so continued with it (fig 4.7).

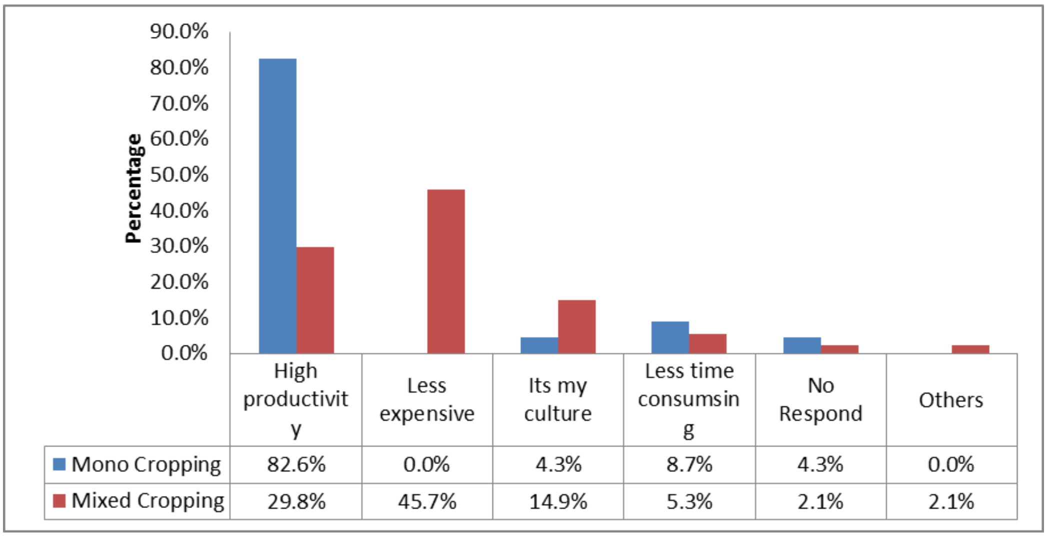


Figure 4.7: Reason for practicing such cropping system

51 % of those who practiced mixed cropping owned the land on which they worked, while 52.3 % of those who practiced mono-cropping did not own the land on which they worked (fig 4.8).

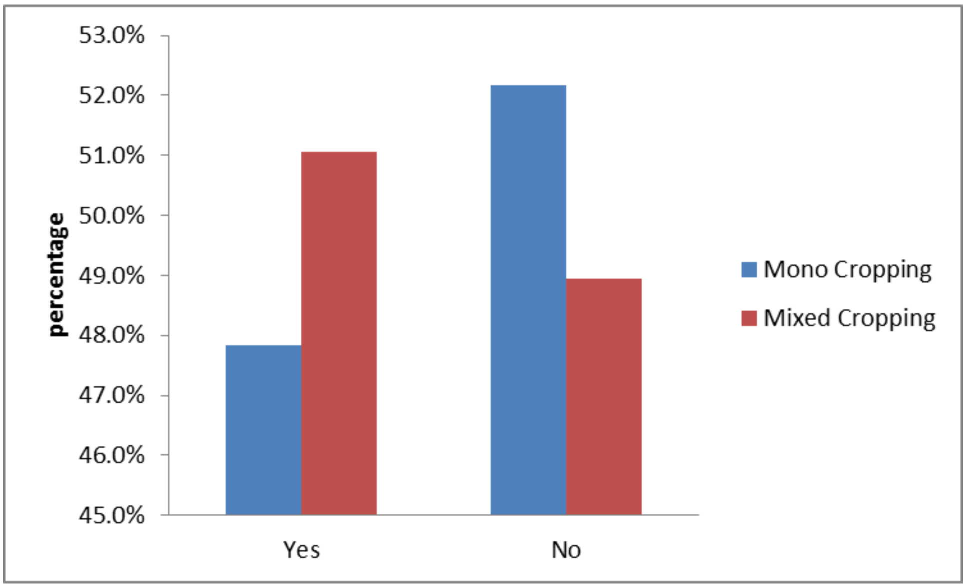


Figure 4.8: Own the land on which you farm

Most of the farms 56.5 % on which mono-cropping was carried out were located on hills while 34 % of the farms on which mixed cropping was carried out were located on hills. 21.7 % of mono-cropping farms and 36.2 % of mixed cropping farms were located on level land. 8.7 % of mono-cropping farms and 21.3 % of mixed cropping farms were situated on slopes as shown in fig 4.9.

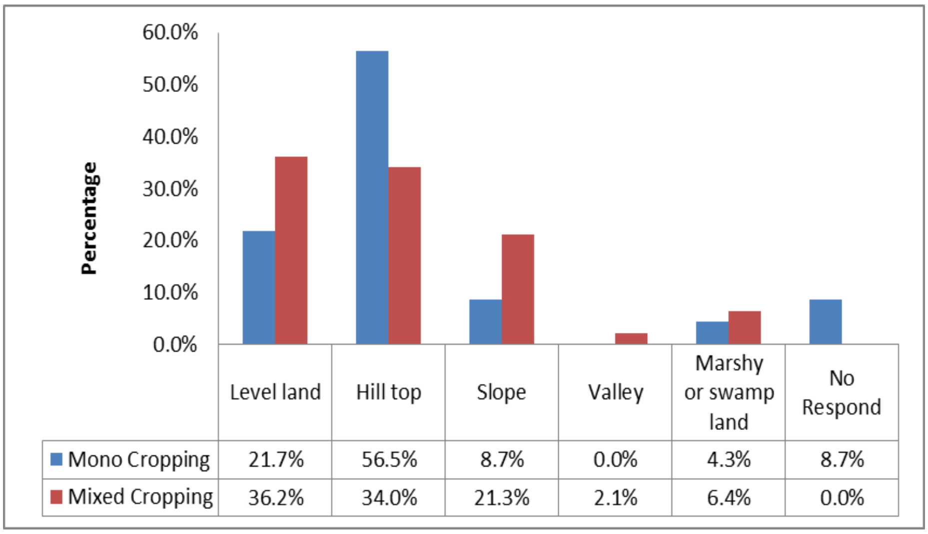


Figure 4.9: Location of farms on which cropping systems were carried out

For those who had farms on slopes, 40 % of those who carried out mixed cropping and 20.4 % of those who practiced mono-cropping farmed across slopes, while 5 % of` those who carried out mixed cropping made ridges along slopes and 0 % of those who practiced mono-cropping made ridges along slopes. 3 % of those who practiced mixed cropping made small mounts as their way of farming on slopes. This is shown in fig 4.10.

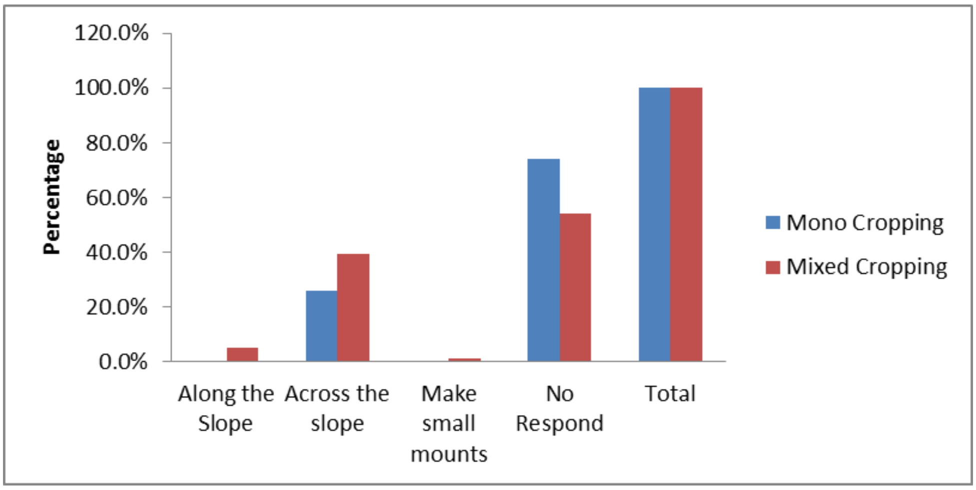


Figure 4.10: How farming was done on slopes by mixed and mono-croppers

60.9 % of farmers who carried out mono-cropping and 42.6 % of farmers who practiced mixed cropping gave as reason for farming commercial. Majority of farmers from mono-cropping systems gave as reason for farming commercial which means they are business oriented. 8.7 % of those who practiced mono-cropping and 14 % of those who carried out mixed cropping system, gave as reason for farming consumption, as seen in figure 4.11.

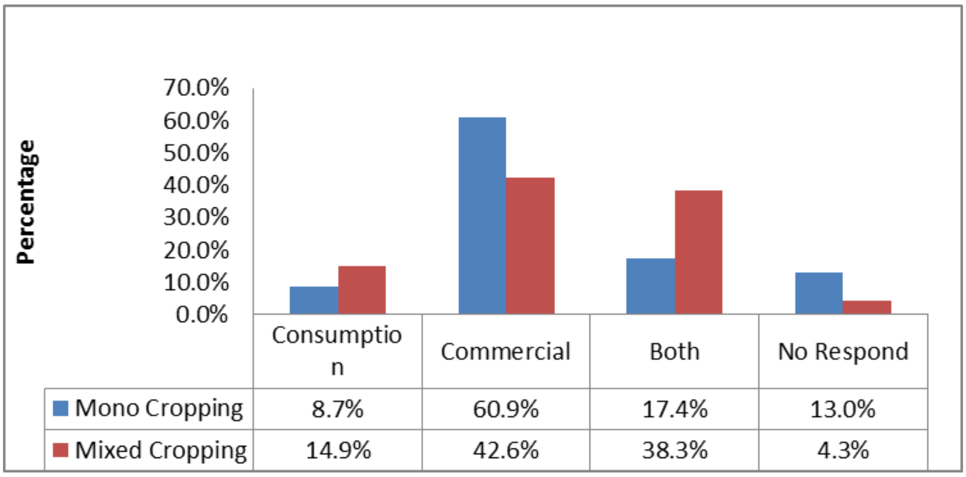


Figure 4.11: Reasons for farming.

Approximately 80.2 % of the farmers from mono-cropping system and 40.7 % of farmers from mixed cropping employed workers to carry out farm work. The percentage of those under mono-cropping is higher than that of mixed cropping, since majority of those who practiced mono-cropping gave as reason for farming commercial. It therefore means there is much farm work, and, therefore, individual and family labor cannot produce higher yields, reason labor has to be employed for higher productivity. Approximately 18 % of those from mono-cropping practices and approximately 38 % of those from mixed cropping system used family labor in carrying out farm work (fig 4.12).

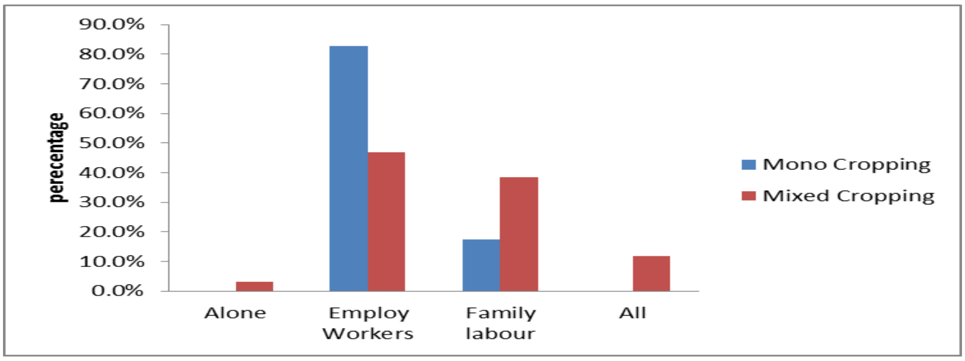


Figure 4.12: How farm work was carried out by farmers in Santa

69.6 % of those from mono-cropping system and 46.8 % of farmers from mixed cropping system sprayed, cleared and tilled their farms as means of preparing their farms for cultivation. Approximately 6 % of those from mono-cropping and approximately 8 % of farmers from mixed cropping system, cleared, burned and tilled their farms as means of preparing farms for planting. Approximately 21 % of farmers from mono-cropping practices and approximately 42 % of those from mixed cropping cleared and buried residue as means of preparing their farms for planting. Majority of the farmers from mono-cropping system sprayed, cleared, and tilled their farms as means of preparing their farms for planting (fig 4.13). This is attributed to the fact farmers who practiced mono-cropping do so for commercial purpose.

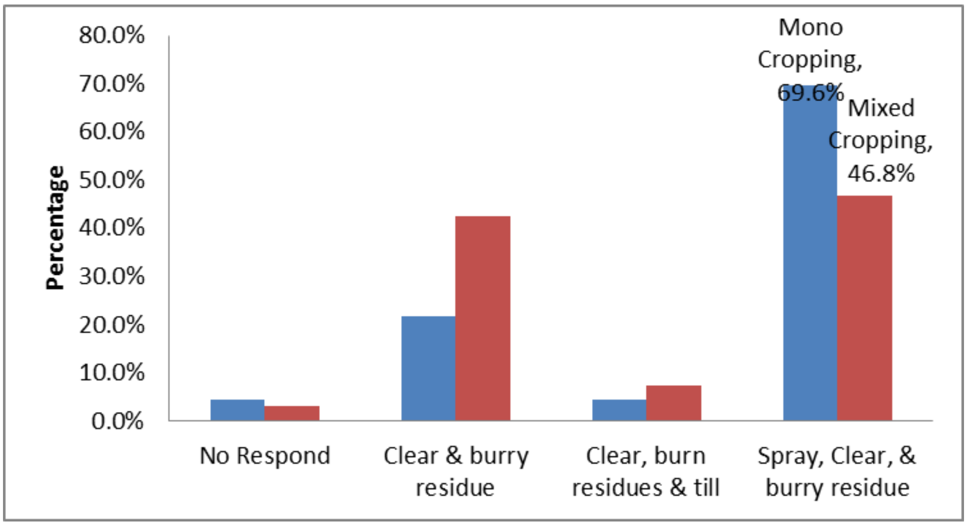
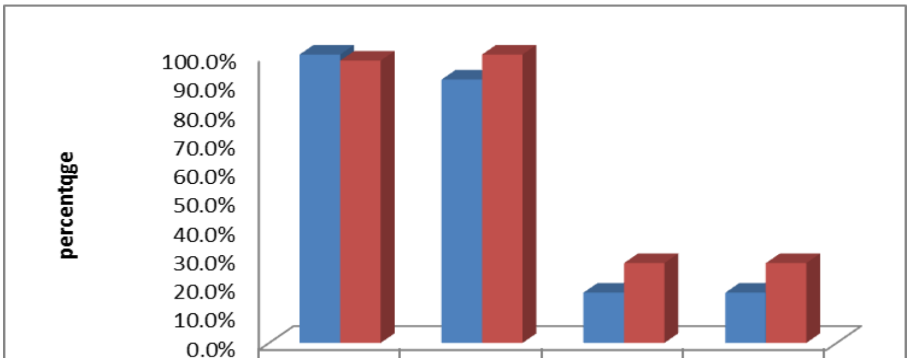


Figure 4. 13: How farms were prepared for planting

100 % of farmers from mono-cropping system and 97.9 % of farmers from mixed cropping system used machetes as one of the equipment in cultivation. Hoes constituted 91.3 % for mono-cropping farmers and 100 % for mix cropping farmers. 17 % of farmers from mono-cropping system and 27.7 % of farmers from mixed cropping used diggers. 17.4 % of farmers from mono-cropping system and 27.7 % of farmers from mix cropping system, used tractors as a cultivation equipment, as seen in fig 4.14.



	Machetes	Hoes	Diggers	Tractors
Mono Cropping	100.0%	91.3%	17.4%	17.4%
Mixed Cropping	97.9%	100.0%	27.7%	27.7%

Figure 4. 14: Equipment used in cultivation by mono and mixed croppers

100 % of those who practiced mono-cropping and 97.9 % of those who practiced mixed cropping, grew Irish potatoes. 78.3 % of farmers from mono-cropping system grew vegetables, while 84 % of those from mixed cropping grew vegetables. 69.6 % of those from mono-cropping grew green spices, whereas 72.3 % of farmers from mixed cropping

grew green spices. Carrot mono-cropping constituted 82.6 % while mixed carrot cropping constituted 70.2 %. Cabbage mono-cropping constituted 91.3 %, while mixed cabbage cropping was 78.7 %. There weren't any maize and beans mono-cropping farms and farmers from mixed cropping who grew maize were 95.7 % and 93.6 % grew beans. 39.1 % of those from mono-cropping and 68.1 % of those from mix cropping grew sweet potatoes, as demonstrated in fig 4.15.

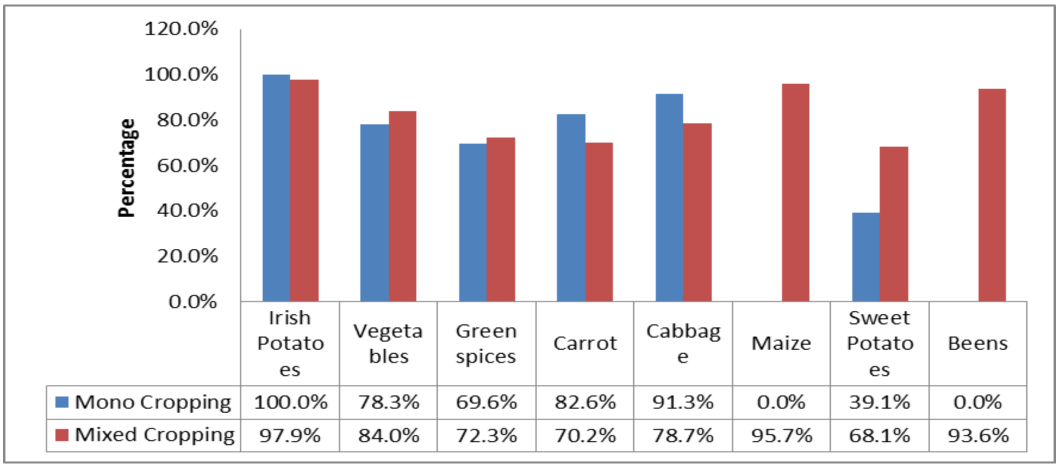


Figure 4.15: Types of crops grown in both cropping Systems

Majority of the farmers approximately 58 % who carried out mono-cropping had been cultivating for a period of between 10-15 years, while most of the farmers 56 % who practiced mixed cropping had been cultivating for a period of between 5-10 years. Mono-cropping has been practiced for a longer period than mixed cropping and no rotation of crops, with the same crop being planted year after year, and with lots of chemicals sprayed on these mono-cropping farms in order to get high productivity. With this continuous mono-cropping practices, there is a high probability of nutrient depletion in soils under this cropping system.

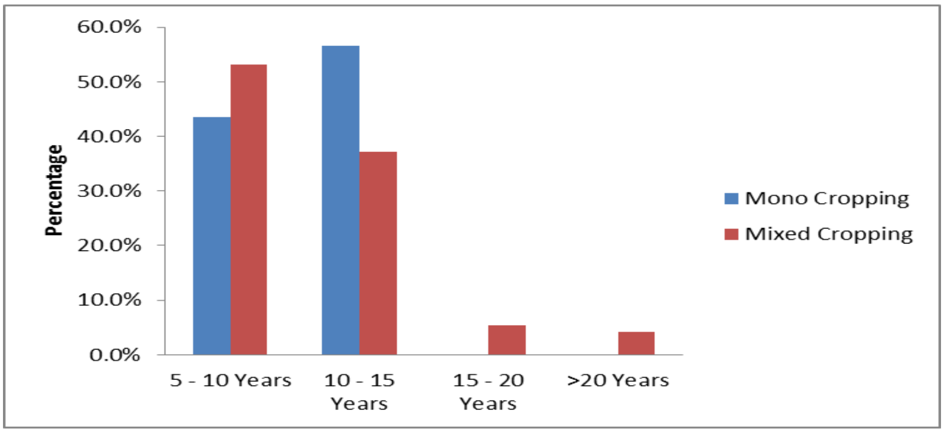


Figure 4.16: Period of crop cultivation

More than 60 % of farmers who carried out mono-cropping system and more than 40 % of farmers who practiced mixed cropping system, cultivated their farms more than twice a year. 30 % of farmers from mono-cropping system and more than 40 % of farmers from mixed cropping, cultivated their farms twice a year, as seen in fig 4.17.

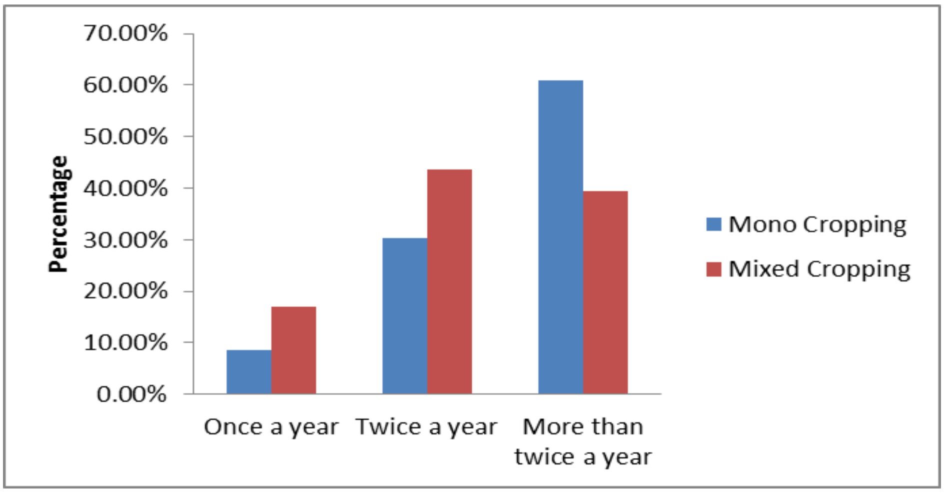


Figure 4.17: Intensity of crop cultivation in a year

Most of the farmers more than 60 % who practiced mixed cropping reared animals alongside farming, and used the animal droppings on their farms as manure. On the other hand, more than 50 % of the farmers who carried out mono-cropping reared animals as well and equally used the animal dung on their farms. The number of those who reared animals alongside farming was more for those who practiced mixed cropping and thus probability of getting more manure than those who carried out mono-cropping (fig 4.18).

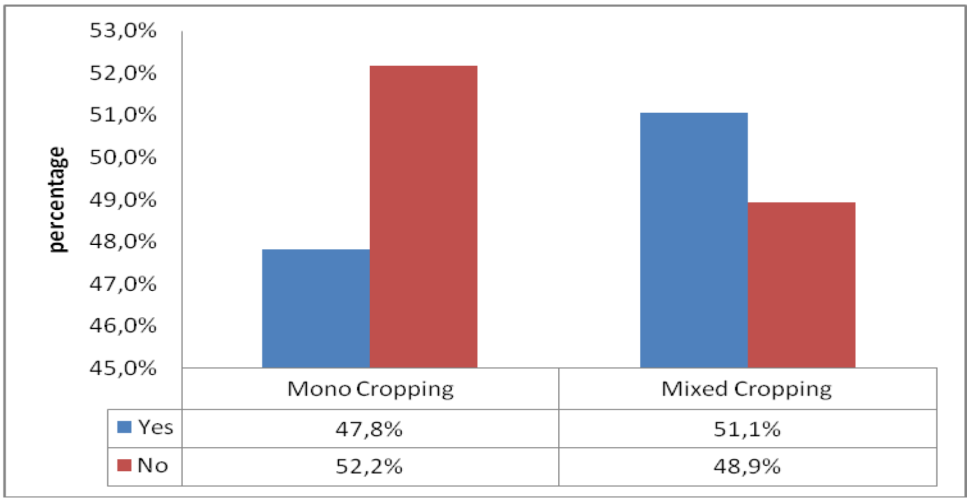


Figure 4.18: Mix farming practices by farmers

4.1.3 Farmers perception about productivity

6.4 % of farmers from mixed cropping and 0 % of farmers from mono-cropping system said productivity increases when they don't use chemical fertilizers, while 100 % of those from mono-cropping and 92.6 % of those from mixed cropping said productivity decreases when they don't use chemical fertilizer. This indicated that farmers who practiced mono-cropping relied on chemical fertilizers as the best way of improving soil fertility, while on the other hand farmers who practiced mixed cropping believed that chemical fertilizer application is not the only best way to improve the soil's fertility.

4.2 Physical and Chemical Characteristics of Soils under Mixed and Mono Cropping Systems in Santa

The results for the physico-chemical characteristics of the soil samples under the mixed and mono cropping systems are presented in appendix 1. The results showed variations and similarities of these properties under the different cropping systems in the study area:

4.2.1 Texture

Textural classes for soils under mono-cropping system ranged from loam, sandy loam, sandy clay loam and sandy clay. That of soils under mixed cropping ranged from loam, loam sand, sandy loam and silt loam.

4.2.2 Bulk density

Bulk density for samples under mono-cropping ranged from0.60-0.86g/cm^3, while that of mixed cropping ranged from 0.62-0.7872g/cm^3. However, the mean value of bulk density (0.72g/cm^3) was recorded under both cropping systems.

4.2.3 Porosity

Porosity for mono-cropping ranged from 67.55-82.45 %, while that of mixed cropping ranged from 61-72.45 %. The mean porosity values for mono-cropping and mixed cropping system were 75.45 % and 70.55 % respectively.

4.2.4 pH and electrical conductivity.

The results showed pH values for soils under mono-cropping ranged from 4.1-6.4, whereas that of soils under mixed cropping was between 5.0-6.8. The pH mean values for soils under mono-cropping and mixed cropping systems were 5.59 and 6.19. Electrical conductivity for soils under mono-cropping and mixed cropping systems were 0.04-0.6 Ms/cm and 0.04-0.0.67 Ms/cm respectively. The mean values of electrical conductivity for soils under mono-cropping and mixed cropping were 0.05 Ms/cm and 0.19 Ms/cm respectively.

4.2.5 Exchangeable acidity

Exchangeable acidity values for soils under mono-cropping and mixed cropping systems ranged from 1.4-13.4.meq/100 g and 3.1-11.1meq/100 g respectively. The mean exchangeable acidity for soils under mono-cropping and mixed cropping systems were 8.26 meq/100 g and 5.74 meq/100 g.

4.2.6 Total nitrogen

Nitrogen value for soils under mono-cropping ranged between 0.14-8.4 %, with a mean value of 1.04 %, while that of soils under mixed cropping ranged from 0.17-0.27 % and a mean value of 0.21 %.

4.2.7 Carbon to Nitrogen ratio

The C/N ratios for soils under mono-cropping ranged from 16.67-27.36, with a mean of 23.35, while that of mixed cropping was between 18.-31.85, with a mean of 22.91.

4.2.8 Available phosphorus

Phosphorus values for soils under mono-cropping ranged from 30.60-90.31 mg/kg, with a mean of 50.27 mg/kg, whereas those of soils under mixed cropping was between 23.60-105.5mg/kg, with a mean of 55.59 mg/kg.

4.2.9 Exchangeable cations

Ca values under mono-cropping ranged from 1.3-2.3 Cmol/kg, with a mean of 1.66 Cmol/kg. That of Mg for soils under mono-cropping was between 1.0-2.3 Cmol/kg, with a mean of 1.31 Cmol/kg. K under mono-cropping ranged from 0.5-0.9 Cmol/kg, with a mean of 0.67 Cmol/kg. Na under mono-cropping was between 0.01-0.1 Cmol/kg, with a mean of 0.02 Cmol/kg. Ca under mixed cropping ranged from 1.1-3.2 Cmol/kg, with a mean of 22.6 Cmol/kg, Mg was between 0.4-2.1 Cmol/kg under mixed cropping, with a mean of 1.50 Cmol/kg, K was between 0.4-0.8 Cmol/kg, with a mean of 0.63 Cmol/kg, and Na under mixed cropping ranged from 0.01-1.3 Cmol/kg, with a mean of 0.39 Cmol/kg.

4.2.10 Cations exchange capacity

The CEC values for soils under mono-cropping ranged from 9.50-15.20 Cmol (+)/Kg with a mean of 11.39 Cmol (+)/Kg. Whereas those under mixed cropping was between 10.20-17.20 Cmol (+)/Kg, with a mean value of 14.62 Cmol (+)/K.

4.2.11 Organic matter

The results showed that the organic matter contents ranged from 4.0 – 5.34 % and 4.07-7.8 % respectively for soils under mono and mixed cropping. The organic matter mean values were 4.68 % and 6.11 % for soils under mono and mixed cropping systems.

4.3 Fertility status of soils under mixed and mono-cropping systems in Santa.

4.3.1 Texture

The results showed that 40 % of the samples under mixed cropping system had a loamy texture, 20 % had a loam sand texture, 20 % were sandy loam and 20 % had a silt loam texture. Whereas 40 % of the samples under mono-cropping system had a loamy texture, 40 % had a sandy loam texture, 10 % was sandy clay loam, and 10 % was sandy clay. Soil texture is an innate property of the soil that does not change with agricultural activities. The main influence of texture is on permeability which decreases with decreasing particle size. An ideal soil texture suitable for plant growth is one with a loamy (comprises of equal proportions of all three particle size) texture according to Landon (1991). Therefore, based on the current study, the soils under mixed cropping in Santa were more suitable for plant growth as compared to that under mono-cropping.

4.3.2 Bulk density

There was no significant difference ($P>0.05$) between bulk density of mixed cropping and that of mono cropping system. The mean of soils under mono-cropping was 0.72 g/cm^3 and that of soils under mixed cropping was equally 0.72 g/cm3. These value according to Landon (1991), are considered high with regards to standard required for agricultural soil. High bulk densities in most agricultural soils are an indication of soil compaction. Compaction in turn results from intensive tillage using hoes, diggers and even tractors. Based on these results and in relation to this characteristic, soil fertility is negatively influenced by both cropping systems.

4.3.3 Porosity

The results also showed that there was a significant difference ($P<0.05$) between total porosity of mixed cropping and that of mono cropping. The mean porosity values for soils under mono-cropping and mixed cropping system were 75.45 % and 70.55 % respectively. Standard total porosity required for suitable agricultural soils lies between 30 % and 70 % (Foth, 1990). The high porosity in soils under mono-cropping can be suggested to be as a result of three reasons: first a greater percentage of the soil had a sandy texture and thus larger macro pore spaces making it more porous. Secondly due to low pH that does not favour microbial activity to generate organic matter and thirdly the low organic matter content in the soil, since organic matter minimizes leaching due to the formation of complexes by organic matter that has the ability to hold substances together (binding agent), hence a loose and porous soil. The results, indicates that soils under mono cropping were more fertile, since it fall closest to the range (70.55 %) for suitable agricultural soils.

4.3.4 pH and electrical conductivity.

The mean pH values for soils under mono-cropping and mixed cropping were 5.59 and 6.19 respectively. This shows that pH of soils under mono-cropping was moderately acidic while that of soils under mixed cropping system was slightly acidic based on the pH range proposed by Beernaert and Bitondo (1992). There was a significant difference ($p<0.05$) between pH values of soils under mono cropping and that under mixed cropping. It can be suggested that the high rate of inorganic fertilizer application under the mono cropping system accounts for its moderately acidic nature. High amounts of inorganic fertilizer application have been reported to increase soil acidity (Landon, 1991) for agricultural soils. Yerima (2012), reported that the soils around the study area are varied, acid in nature, have low nutrient contents and compact and dense structures that are an impediment for plant growth. He added that the soils are reddish in color and basically rich in oxides of Aluminum and Iron (sesquioxides). However, under both cropping systems pH were not below 5.5, because at pH level below 5.5 the exchange sites are occupied by H^+ and Al^{3+}. Therefore, the soils were less prone to aluminium toxicity. With these results, mixed cropping had a positive influence on soil fertility than mono-cropping system.

The mean EC value for soils under mono and mixed cropping systems were 0.31 ms/cm and 0.11 ms/cm respectively. The high electrical conductivity for soils under mono-cropping could be accounted for by its low cation exchange capacity. Higher electrical conductivity indicates greater tendency for exchange sites to be occupied by anions instead of cations, which could be linked to its moderately acidic nature. Therefore based on these results, soil fertility is positively influenced by mixed cropping with low electrical conductivity and high cations exchange capacity, since plants absorb majority of essential minerals as cations. There were significant ($p<0.05$) differences in the electrical conductivity of soils under mono and mixed cropping systems.

4.3.5 Exchangeable acidity

The mean exchangeable acidity for soils under mono-cropping and mixed cropping systems were 8.26 meq/100 g and 5.74 meq/100 g respectively. There was a significant difference ($p<0.05$) between exchangeable acidity of soils under mono cropping and that under mixed cropping system. The result shows that EA under mono-cropping was higher than the required range proposed by Beernaert and Bitondo (1992) while that under mixed cropping practices fall within the required range. Intensive cultivation and application of inorganic fertilizers lead to higher exchangeable acidity content. The results of this study were in agreement with those reported by different researchers (Baligar *et al*., 1997; Wakene, 2001), who reported that inorganic fertilizer application is the root cause of soil acidity. With these results, it indicates lower pH value in soils under mono-cropping and at low pH soil microbial activity is inhibited, thus low OM and consequently reduced sources of nutrients (N, P, S and micronutrients that promote plant growth) and this negatively affects soil fertility.

4.3.6 Total nitrogen

The results showed mean nitrogen values for soils under mono-cropping and mixed cropping systems were 1.04 % and 0.21 % respectively. The result showed that soil nitrogen content was higher in mono cropping system compared to the mixed cropping system. This can be suggested to be due to the high fertilizer applications rates since all the different crops which farmers planted under mono cropping systems (cabbage, celery, Irish potato, huckle berry) were non-leguminous. Remarkably, the difference between the nitrogen content of soils under mono cropping and that under mixed cropping was not significant ($p>0.05$). It can be suggested that this was as a result of the nitrogen fixation by the leguminous crops which farmers planted (beans, soya bean, and cow pea) under the mixed cropping system. High nitrogen content influences soil fertility more, therefore, based on these results mono-cropping influenced soil fertility positively in relation to this property.

4.3.7 Carbon to Nitrogen ratio

The mean C/N for soils under mono-cropping and that under mixed cropping were 23.35 and 22.91 respectively. These values are considered poor/high according to the range proposed by Beernaert and Bitondo (1992).There was no significant difference ($p>0.05$) between the C/N ratio in both cropping systems. C/N is important for microbial activity. When it is high, it's an indication of the presence of high carbon and micro-organisms don't feed on carbon. When it is high, it inhibits soil micro-biodiversity. The slightly higher C/N ratio of soils under mono-cropping system could be due to moderately acidic nature of the soil, and this does not stimulate micro-organisms and therefore the production of OM is reduced and subsequently high CO2 is evolved and decomposition is anaerobic. Therefore based on these results it indicated that mixed cropping influenced soil fertility more.

4.3.8 Available phosphorus

The results showed that the mean phosphorus values of soils under mono and mixed cropping systems were 50.27 mg/kg and 55.59 mg/kg respectively. There was no significant difference ($p>0.05$) in the phosphorus contents of soils under mixed and mono cropping systems. The results showed that available soil P level under both cropping systems, were >15 mg/kg which falls within the high range described by Beernaert and Bitondo (1992). The high contents of P observed in the soils of both cropping systems are in agreement with the results reported by some authors (Murphy, 1968; Eylachew, 1987) that the availability of P under most agricultural soils increase by addition of inorganic fertilizers (NPK). However, the P content of soils under mixed cropping was higher than that of soils under mono-cropping. This is an indication that mixed cropping system influenced soil fertility positively in relation to this parameter more than mono-cropping system.

4.3.9 Exchangeable cations

The results showed that the exchangeable cations mean values for soils under mono-cropping were 1.66 Cmol (+) kg, 1.31 Cmol (+) kg , 0.67 Cmol (+) kg, and 0.02 Cmol (+) kg respectively for Ca^{2+} , Mg^{2+}, K^{+}, and Na^{+}. Whereas the exchangeable cations mean values for soils under mixed cropping were 22.6 Cmol (+) kg, 1.50 Cmol (+) kg, 0.63 Cmol (+) kg, and 0.39 Cmol (+) kg respectively for Ca^{2+}, Mg^{2+}, K^+, and Na^+. The calcium values are considered very low for mono cropping system and very high for mixed cropping system, based on the range proposed by Beernaert and Bitondo (1992). The Mg value for mono cropping was low, whereas that of mixed cropping was medium following the ranged stipulated by Beernaert and Bitondo (1992). The K values were high for both cropping systems, and the Na values were very low for mono-cropping and medium for mixed cropping system (Beernaert and Bitondo, 1992). It can be suggested that the lower exchangeable cations under the mono-cropping system was due to leaching of basic cations (Mg^{2+}, Ca^{2+}, Na^+ and K^+). This explains why soils under mono-cropping were more acidic than those under mixed cropping, since the H^+ and Al^{3+} ions had occupied the exchange sites, due to low pH. Previous findings have also considered these factors and the application of acid forming fertilizers as major factors affecting the distribution of K^+ in soil systems mainly enhancing its depletion especially in tropical soils (Baker *et al.*, 1997; Wakene, 2001). However there were significant differences ($p<0.05$) in the Ca^{2+}, Na+ and Mg^{2+} contents in soils under both cropping systems, while there was no significant difference ($p>0.05$) in the K+ contents of soils under both cropping systems. Based on these results, it indicated that soils under mixed cropping system had more exchangeable bases than soils under mono-cropping system. These exchangeable bases adds to the buffering capacity of the soil making it slightly acidic that stimulates microbial activity to generate more OM which is an important source of soil nutrients required for plant growth. Therefore, in relation to this property, mixed cropping enhanced soil fertility more.

4.3.10 Cations exchange capacity

The cation exchange capacity mean values for soils under mono and mixed cropping systems were 11.39 Cmol (+)/Kg and 14.62 Cmol (+)/Kg respectively. The low CEC value based on the range given by Beernaert and Bitondo (1992), in soils under mono-cropping might be attributed to its low pH, since its exchange sites have been occupied more by anions instead of basic cations that provides more sources of soil nutrients necessary for plant growth. There were significant differences ($p<0.05$) in the CEC of soils under both cropping systems. With these results, it showed that soils under mixed cropping positively affected soil fertility.

4.3.11 Organic matter

The results showed that the mean organic matter values were 4.68 % and 6.11 % for soils under mono-cropping and mixed cropping respectively. There was a significant difference ($p<0.05$) between the OM of soils under both cropping systems. The higher OM of soils under mixed cropping is suggested to be due to its slightly acidic nature which favours microbial activity, to generate organic matter. OM does not only provide energy for microbial activity, but it is an important source of nutrients needed for plant growth. OM also aids in water management as residues protect the soil surface from rain drop impacts. This intends minimizes leaching, since organic substances have the ability of holding substances. Higher OM is a good indication of fertile soils, thus mixed cropping enhanced soil fertility more under this parameter.

Therefore using the model in this study

For mono cropping system $P_l + BD_l + CEC_l + pH_l + OM_l + N_l + EA_l + EC_l = 50\text{-}75$ (low fertility)

For mixed cropping system $P_l + BD_l + CEC_l + pH_l + OM_l + N_l + EA_l + EC_l = 75\text{-}100$ (Medium fertility).

These results indicated that soils under mixed cropping system were more fertile than soils under mono cropping system

4.4 Challenges faced by farmers who practiced mixed and mono-cropping systems in Santa sub-division

All the farmers 100 % who carried out mono-cropping practices and over 80 % of those who practiced mixed cropping had noticed a decrease in soil fertility as illustrated in fig 4.19.

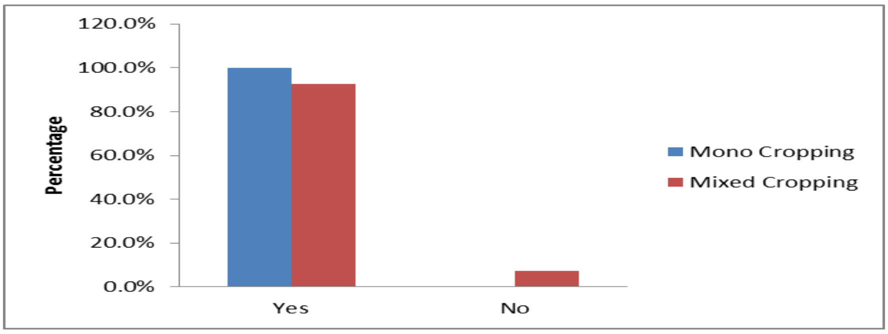


Figure 4.19: Any change in soil fertility status?

Nutrient shortages, soil acidity, loss of top soil, soil compaction (formation of hard pans), shortages of water, destruction of irrigation pipes by cattle, were difficulties encountered by farmers from both cropping systems. These difficulties could be suggested to have greatly contributed to a decrease in the soil fertility status.

56.5 % of farmers who practiced mono cropping and 40.4 % of farmers who did mixed cropping gave as one of the parameters justifying decrease in soil fertility as more use of manure. 17.4 % of farmers from mono cropping and 35.1 % of farmers who carried out mix cropping, gave as another parameter justifying a decrease in soil fertility as the use of more chemical/inorganic fertilizers (fig 4.20).

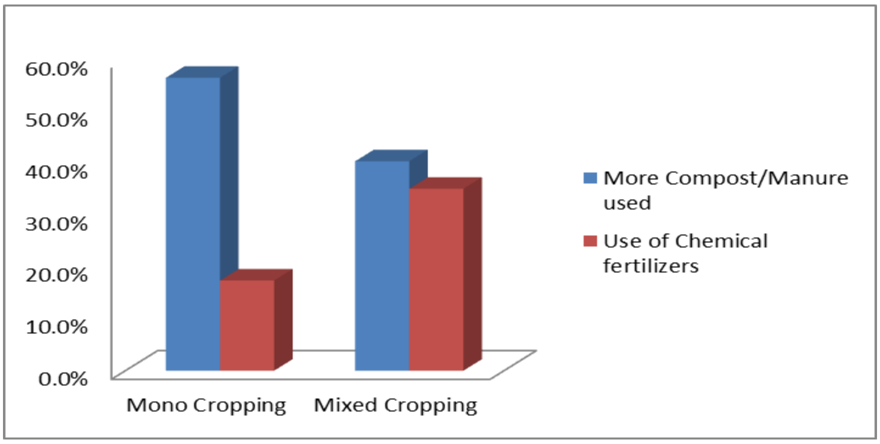


Figure 4.20: Parameters justifying decrease in soil fertility status

The following farm management practices were used by farmers practicing mixed and mono-cropping systems in Santa sub-division to improve upon the soil quality;

4.4.1 Use of inorganic/chemical fertilizers

Several composition of NPK fertilizers used constituted 17.4 % for mono-cropping and 17 % for mixed cropping. Urea constituted 4.3 % for mono-cropping system and 13.8 % for mixed cropping. 4.3 % of the farmers who practiced mono-cropping and 2.1 % of those who carried out mix cropping used potash. Milla complex constituted 0 % for mono-cropping and 3.2 % for mixed cropping. This is shown in fig 4.21. Those practicing mono-cropping used more of potash and several composition of NPK fertilizers, while farmers who carried out mixed cropping used more of urea. More potash was used for mono-cropping since all the farmers 100 % of them grew Irish potatoes.

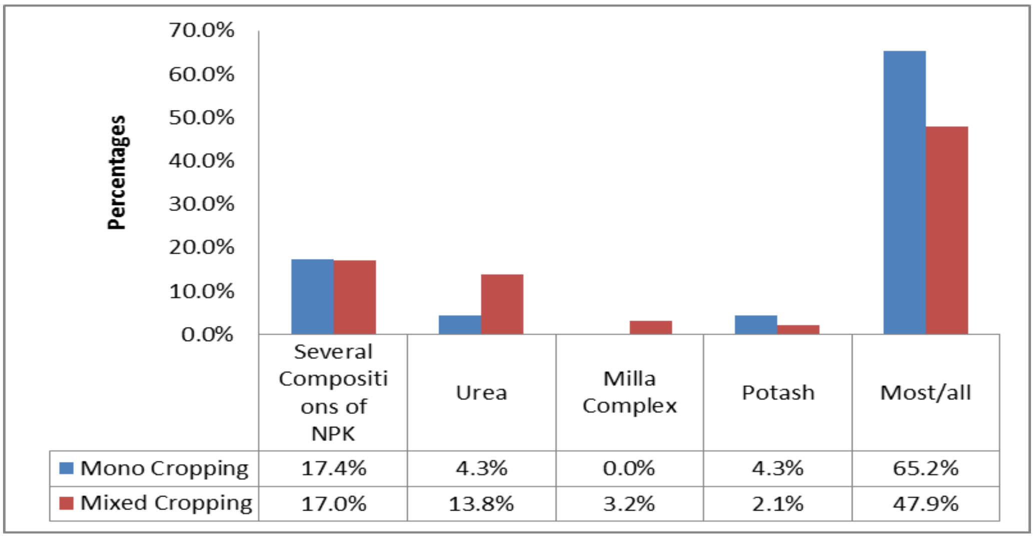


Figure 4.21: Fertilizers used by mixed and mono-croppers

4.4.2 Use of irrigation system

More than 80 % of the farmers who practiced mono-cropping and more than 70 % of farmers who carried out mixed cropping, had either stream/river by their farms, and used it to channel water to their farms to add to the soil moisture to enhance soil fertility.

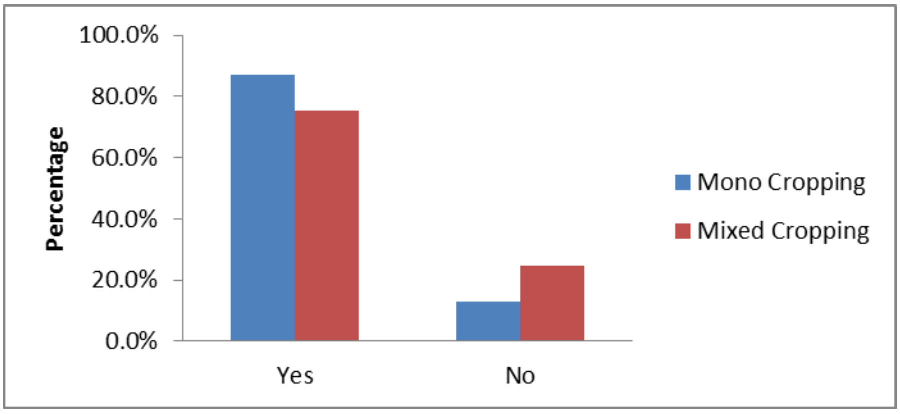
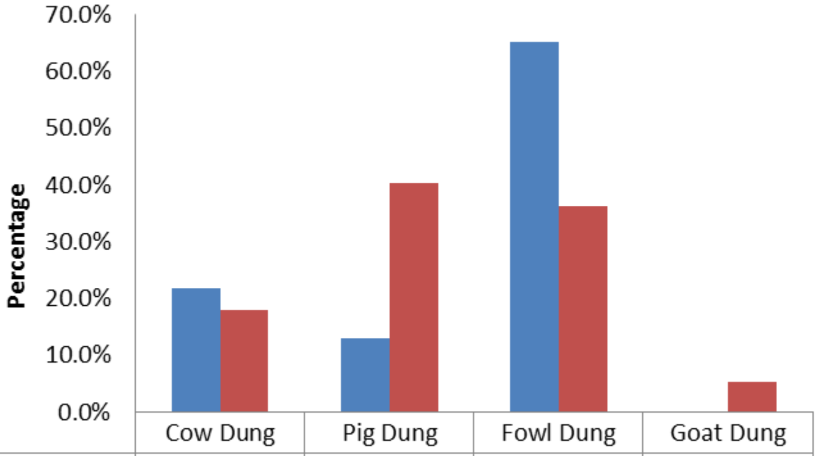


Figure 4. 22: Farm close to any river/stream

4.4.1. Use of animal droppings

21.7 % of farmers from mono-cropping and 18.1 % of farmers from mix cropping used cow dung on their farms. 13 % of farmers from mono-cropping and 40.4 % of farmers from mixed cropping used pig dung on their farms. Fowl dung constituted 65.2 % of farmers fom mono-cropping and 36.2 % offarmers from mixed cropping. Very few of them used goat droppings, consttituting 0 % for farmers who practiced mono-culture and 5.3 % for those who carried out mixed cropping.



	Cow Dung	Pig Dung	Fowl Dung	Goat Dung
Mono Cropping	21.7%	13.0%	65.2%	0.0%
Mixed Cropping	18.1%	40.4%	36.2%	5.3%

Figure 4. 23: Types of animal droppings used by mixed and mono-croppers

4.5 Implication of the results

There were significant differences in porosity, pH, exchangeable acidity, cation exchange capacity, Sodium and magnesium contents of soils under mixed and mono-cropping systems. On the other hand, there were no significant differences in bulk density, nitrogen content, Carbon to nitrogen ratio, calcium, potassium and available phosphorus. Lower pH, higher exchangeable acidity, lower exchangeable cations, and lower cations exchange capacity in soils under mono-cropping indicates soil fertility is negatively affected by this cropping system coupled with unsustainable farming practices. On the other hand, higher pH, lower exchangeable acidity, higher exchangeable cations, and higher cation exchange capacity in soils under mixed cropping system influences soil fertility positively. If sustainable farming measures are not taken under mono-cropping system to promote the soil fertility, and even under mixed cropping system as well to improve and maintain the soil fertility, the land might be subjected to land degradation, and this area will suffer from food insecurity. These sustainable farm management measures will not only improve upon the fertility of the soils but also ensure sustainable agricultural production for future generations.

4.6 Limitations of the study

Some of the difficulties encountered in the field in the course of this research included: Climatic constraints: Due to torrential rainfall, it made it difficult actually to execute the researcher's activities within the time programmed. Inaccessibility of some areas due to consistent rainfall, made field observations limited.

Most of the farmers didn't actually know the names of various fertilizers they used, so the researcher had to visit a local fertilizer vendor to give both the common names known so well by the local farmers and the English names of the fertilizers they used. This took some time and made the researcher extended her time scale for questionnaire administration.

Also the event of land subsidence on two gold miners whose lifeless bodies were discovered with the help of an excavator four days from the day of land subsidence, made the individuals not to fill in the questionnaires on the days assigned for that village (Njong). This made the researcher push forward questionnaire administration in that village to a different day, and this as well extended the time the researcher had in mind for questionnaire administration.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATION

5.1 Summary of findings

1. There were variations and similarities in the physical and chemical characteristics of soils under mixed and mono-cropping systems. Soils under the two cropping systems were significantly different in porosity, pH, exchangeable acidity, electrical conductivity, cation exchange capacity, organic matter and exchangeable bases. On the other hand, there were no significant differences in the bulk density, nitrogen content, C/N, potassium and available phosphorus.

2. Although Porosity, exchangeable acidity, total nitrogen, and carbon to nitrogen ratio, were higher for soils under mono-cropping practices, they were lower for soils under mixed cropping practices. Whereas pH, exchangeable cations, organic matter content, and cation exchange capacity were lower for soils under mono-cropping practices, they were higher for soils under mixed cropping system. These results indicated soils under mixed cropping system had a better quality than that of mono-cropping.

3. Soil acidity, soil compaction, loss of top soil, nutrient shortages, shortage of water and destruction of irrigation pipes by cattle were some of the challenges faced by farmers under mixed and mono cropping systems. Use of chemical fertilizers, irrigation systems, and animal droppings were measures employed by farmers for both cropping systems to improve the soil quality.

5.2 Conclusion

The soil pH under mono-cropping systems is less suitable for most soil chemical reactions compared to that under mix cropping. The levels of exchangeable bases, cations exchange capacity, and organic matter were lower in mono-cropping system as compared to that of mixed cropping system. On the other hand, total nitrogen, exchangeable acidity, and electrical conductivity values were higher for mono-cropping system, while they were lower for mixed cropping system. Therefore it can be concluded that soils under mixed cropping systems have a better quality than those under mono-cropping systems in Santa. These variations in soil physical and chemical properties of mixed and mono-cropping systems indicates the risk of land degradation, and consequently failure in the delivery of ecosystem services, which can lead to low crop production and food insecurity in the area if sustainable agricultural measures are not put in place.

5.3 Recommendations

After assessing soil quality status under mixed and mono-cropping systems, the following recommendations could be of utmost importance,

Improving and maintaining soil quality under both cropping systems.

Rotation of crops from season to season influences soil fertility. Crop rotation should be practiced for those who carry out mono-cropping especially, to help restore the soil fertility by planting a nutrient demanding crop the previous year followed by a low nutrient requirement crop, and also to minimize the spread of weed and diseases, rather than planting the same crop year after year. *E.g.* plant soya beans this year and the next year plant maize. Soya beans give out nutrients to the soil that maize need to grow effectively. Soil life declines when the same crop is grown continuously on the same land, and even if chemical fertilizer is added to the soil without the right proportion and the right fertilizer for the right crops, there will come a time when the land will be so infertile. Therefore rotating several species of crops year after year will help restore soil fertility and reduce the spread of diseases. When crops are rotated, it promotes a variety of living organisms in the soil.

Alliance farming could be practiced under mono cropping. This could help reduce the excess use of chemical fertilizers, and encourage the use of animal manure. Also the number of cattle grazing on the mono-crop land after harvesting should not exceed the carrying capacity, so as to prevent the formation of hard pans that will make the soils very porous and susceptible to erosion.

High-quality labor should be encouraged and stop the use of tractors for tilling and chemicals, for spraying the grass for both cropping systems.

Farms should be cleared rather than burnt for both cropping practices, because when farms are burnt, it destroys the organic matter providing food for all living elements in the soil, kills or drives away a large number of animals, insects, micro-organisms and useful plants. Fire sweeping over the same land year after year leads to the permanent loss of some plant and animal species. Only a handful of fire-resistant plants and organisms remain in the fields. Fire year after year, makes the grass grow in tuffs instead of being spread all over the ground surface, and this enhances soil erosion, (erosion brings destruction to soil structure because soil crumbs are broken up and air can no longer circulate in the soil) leading to a drop in soil fertility.

Maize and beans can be intercropped successfully just like other cereal and legume associations. When maize and beans are inter-planted, their roots overlap. They differ widely in many respects in their growth patterns and nutrients requirements, in the quality of the nutrients looked for, in the way their roots take up these nutrients. The most active periods of nutrients uptake do not coincide (enhances soil fertility). On the other hand, when cocoyam and sweet potatoes are intercropped, they exploit the soil together. These plants have fibrous roots systems that penetrate in depths rather than spread through the soil. Both manage to thrive while making mutual concessions. As both plants have abundant leafing, the main task in this association is to prevent the sweet potatoes leaves from choking the cocoyam foliage and the cocoyam leaves from robbing its companion of light. Pushing back the creeping potatoes stems that might choke the cocoyam/cutting back the cocoyam leaves are best solutions to resolve these problems faced in this intercropped system.

Proper spacing of seedlings during planting is paramount and should be encouraged under both cropping systems. A seedling per hole enhances soil fertility in that, there isn't any overlap of roots since food in the area exploited by the roots of this plant is not limited, and nutrients are not completely pulled out of the soil. On the other hand, a hole with three seedlings planted (dibbling), the roots of the three plants get entangle. These seedlings with entangled roots all need the same amount of water and food at the same time of the agricultural season because their cycle evolve simultaneously, since food in the area exploited by the roots is limited, the three seedlings have to share the available soil nutrients. This causes low productivity in produce and poor food quality. Two plants of same species tend to compete for soil nutrients when their roots are entangled. Admittedly dibbling is advisable provided only a few seeds are sown per hole, and the holes are far enough (60cm) apart to allow the plants room for spreading.

Sow intercrop plants at the same time, to avoid one crop extracting nutrients from another. For example planting groundnuts and then, later on, plant maize, the young maize shoots must snatch soil nutrients from groundnut with well-established roots. Also planting maize before groundnuts will cause the well-established maize stems over shading the young groundnut shoots from sun light while their strong roots compete with the weaker roots of the young groundnut shoots. Groundnuts and maize sown at the same time develop without much competition.

Mixed cropping system should be encouraged, some of the farmers practicing mono-cropping can change to mixed cropping system, since they will have variety of crops grown and added to the fact that land degradation will be prevented to ensure sustainable agricultural production.

Under mono cropping system, acid tolerant varieties can be planted, since these varieties can survive in the acidic condition.

Organic farming should be practice more, rather than the use of chemical fertilizers, since these fertilizers slow down activity of soil organisms that produces organic matter, which is a basic requirement for plant growth.

Measures to reduce challenges faced by farmers who practice mixed and mono-cropping systems.

There is a need to have a soil management programme organized possibly by the Ministry of Agriculture and Rural Development to maintain soil quality in Santa Sub-division. This programme will carry out the following activities:

- Sensitize farmers on the use of chemical fertilizers and its application. Chemical fertilizers if not properly applied in the right proportion poison micro-organisms, and cause the deterioration of soil structure and pose difficulties for ploughing. Farmers need to know how to combine organic fertilizers with chemical fertilizers.
- Train farmers on best sustainable farming practices that enhance soil fertility ensuring conservable agricultural production. Some of these sustainable farming practices should include, reduce tillage, permanent soil cover, integrate crop and livestock production and the use of compost to help boost the fertility of the soil. Transfer of knowledge about INM (Integrated nutrient management) practices to these farmers, will be of utmost importance in improving the soil fertility in this area.

5.4 Suggested areas for further research

A similar study like this in the other villages of Santa Sub-division could enable one to easily draw conclusions on changes in soil quality under these cropping systems in Santa, North West region of Cameroon.

A research could be done on farmer's knowledge on organic and inorganic fertilizers and their application.

A research could be done on impacts of chemical fertilizers -grown crops on human health.

A research could be done on impacts of chemical fertilizers on water quality.

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APPENDICES

Appendix 1: physical and chemical characteristics of soils under mixed and mono-cropping systems in Santa.

Samples	Texture		Bulk density	Porosity	Electrical conductivity	pH	Exchangeable acidity	Organic matter		Exchangeable cations Cmol(+)/Kg		Cation exchange capacity Cmol(+)/Kg	Available phosporus (mg/kg)
Mono 1	Coarse sand	18.02	0.80	69.81	0.04	4.7	12.5	OC (%)	4.77	Ca	2.1	9.50	46.31
	Fine sand	49.57						OM (%)	8.23	Mg	1.4		
	Silt	16						N(%)	0.19	K	0.7		
	Clay	14						C/N	25.45	Na	0.01		
Mono 2	Coarse sand	16.08	0.70	67.71	0.05	5.6	9.5	OC (%)	5.34	Ca	2.3	10.32	44.23
	Fine sand	50.57						OM (%)	9.21	Mg	1.3		
	Silt	16.6						N(%)	0.23	K	0.7		
	Clay	14.75						C/N	23.21	Na	0.02		
Mono 3	Coarse sand	18.02	0.75	82.45	0.04	6.0	11.1	OC (%)	5.02	Ca	1.7	15.20	30.60
	Fine sand	46.03						OM (%)	8.63	Mg	1.1		
	Silt	21						N(%)	0.21	K	0.6		
	Clay	14.95						C/N	23.90	Na	0.01		
Mono 4	Coarse sand	11.02	0.86	67.55	0.7	4.1	13.4	OC (%)	4.71	Ca	1.5	9.10	45.65
	Fine sand	51.08						OM (%)	8.12	Mg	2.0		
	Silt	16						N(%)	0.17	K			

											0.7		
	Clay	14						C/N	27.36	Na	0.01		
Mono 5	Coarse sand	15.02	0.80	77.55	0.05	5.7	10.1	OC (%)	4.77	Ca	2.0	10	40.10
	Fine sand	51.08						OM (%)	8.23	Mg	1.8		
	Silt	19						N(%)	0.19	K	0.6		
	Clay	16						C/N	25.45	Na	0.01		
Mono 6	Coarse sand	13.02	0.67	78.55	0.05	4.4	7.1	OC (%)	4.60	Ca	1.7	12	35.10
	Fine sand	50.08						OM (%)	7.9	Mg	1.3		
	Silt	22						N(%)	0.20	K	0.8		
	Clay	16						C/N	23.00	Na	0.01		
Mono 7	Coarse sand	10.07	0.75	79.71	0.6	5.7	8.5	OC (%)	4.71	Ca	1.6	9.32	45.23
	Fine sand	51.52						OM (%)	8.12	Mg	2.3		
	Silt	14.6						N(%)	0.19	K	0.9		
	Clay	16.75						C/N	24.79	Na	0.01		
Mono 8	Coarse sand	12.31	0.62	78.85	0.04	6.3	7.8	OC (%)	4.50	Ca	20.0	11	40
	Fine sand	44.00						OM (%)	7.74	Mg	1.5		
	Silt	18						N(%)	0.27	K	0.6		
	Clay	15.69						C/N	16.67	Na	0.01		
Mono 9	Coarse sand	13.12	0.60	79.90	0.8	4.7	1.20	OC (%)	4.0	Ca	1.3	13.41	90.31
	Fine sand	49.99						OM (%)	7.43	Mg	1.0		

	Silt	24.89						N(%)	0.18	K	0.6		
	Clay	12						C/N	24.00	Na	0.01		
Mono 10	Coarse sand	13.08	0.61	72.40	0.6	6.0	1.4	OC (%)	4.4	Ca	1.9	14.00	85.14
	Fine sand	54.11						OM (%)	9.12	Mg	1.2		
	Silt	13						N(%)	0.27	K	0.5		
	Clay	19.81						C/N	19.63	Na	0.1		
Mix 1	Coarse sand	23.12	0.76	69.40	0.07	6.1	3.20	OC (%)	6.32	Ca	1.4	12.31	98.31
	Fine sand	39.99						OM (%)	7.43	Mg	0.86		
	Silt	27.89						N(%)	0.23	K	0.8		
	Clay	9						C/N	18.78	Na	0.01		
Mix 2	Coarse sand	21.02	0.78	70.57	0.06	5.9	4.20	OC (%)	5.8	Ca	1.2	19.10	105.51
	Fine sand	43.99						OM (%)	9.21	Mg	0.87		
	Silt	24						N(%)	0.22	K	0.7		
	Clay	10						C/N	24.04	Na	0.01		
Mix 3	Coarse sand	18.01	0.74	72.45	0.04	6.4	11.1	OC (%)	5.46	Ca	3.2	10.20	10.60
	Fine sand	49.11						OM (%)	7.69	Mg	2.1		
	Silt	20						N(%)	0.14	K	0.7		
	Clay	10						C/N	31.85	Na	0.01		
Mix 4	Coarse sand	21.01	0.78	71.81	0.06	5.7	4.6	OC (%)	5.1	Ca	1.8	15	44
	Fine sand	44.00						OM (%)	8.77	Mg	0.90		

	Silt	22						N(%)	0.25	K	0.8		
	Clay	12						C/N	20.4	Na	0.02		
Mix 5	Coarse sand	18.08	0.77	70.40	0.52	5.4	3.4	OC (%)	5.3	Ca	1.9	14	42
	Fine sand	49.11						OM (%)	9.12	Mg	1.2		
	Silt	20						N(%)	0.25	K	0.5		
	Clay	10						C/N	21.2	Na	0.1		
Mix 6	Coarse sand	20.00	0.64	71.45	0.04	5.6	3.1	OC (%)	4.07	Ca	1.1	12.20	23.60
	Fine sand	47.03						OM (%)	8.63	Mg	0.7		
	Silt	21						N(%)	0.21	K	0.4		
	Clay	11.97						C/N	19.38	Na	0.02		
Mix 7	Coarse sand	21	0.67	72.45	0.06	6.8	2.6	OC (%)	7.05	Ca	2.5	13	60.80
	Fine sand	43.4						OM (%)	11.61	Mg	2.4		
	Silt	21						N(%)	0.20	k	0.6		
	Clay	11.80						C/N	20.3	Na	0.4		
Mix 8	Coarse sand	22	0.69	73	0.6	6.8	3.6	OC (%)	6.8	Ca	2.8	17.20	72.56
	Fine sand	42.9						OM (%)	10.8	Mg	1.2		
	Silt	23						N(%)	0.20	K	0.6		
	Clay	11.7						C/N	23.1	Na	0.5		
Mix 9	Coarse sand	21	0.70	73	0.58	6.5	7.2	OC (%)	7.8	Ca	1.9	16.48	67.46
	Fine sand	11.76						OM (%)	9.4	Mg	0.9		

	Silt	28						N(%)	0.29	K	0.4		
	Clay	10						C/N	26	Na	1.3		
Mix 10	Coarse sand	12	0.62	61	0.52	5.95	7..6	OC (%)	7.4	Ca	2.7	16.67	31.09
	Fine sand	58.67						OM (%)	12.0	Mg	2.6		
	Silt	23						N(%)	8.4	k	0.8		
	Clay	11.8						C/N	24	Na	1.5		

Where Mono = Mono-cropping and Mix = Mixed cropping

Appendix 2: Analysis of variance between the chemical and physical characteristics of soils under mixed and mono-cropping systems in Santa.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Bulk density	Between Groups	.000	1	.000	.001	.977
	Within Groups	.105	18	.006		
	Total	.105	19			
Porosity	Between Groups	119.805	1	119.805	5.528	.030
	Within Groups	390.130	18	21.674		
	Total	509.935	19			
Electrical conductivity	Between Groups	.108	1	.108	5.432	.032
	Within Groups	.358	18	.020		
	Total	.466	19			
pH	Between Groups	1.824	1	1.824	5.703	.028
	Within Groups	5.757	18	.320		
	Total	7.581	19			
Exchangeable acidity	Between Groups	67.345	1	67.345	5.326	.033
	Within Groups	227.613	18	12.645		
	Total	294.958	19			
Nitrogen	Between Groups	3.436	1	3.436	1.027	.324
	Within Groups	60.230	18	3.346		
	Total	63.666	19			
Carbon to nitrogen ratio	Between Groups	.972	1	.972	.078	.783
	Within Groups	223.828	18	12.435		
	Total	224.800	19			
Calcium	Between Groups	1.800	1	1.800	4.623	.045

	Within Groups	7.008	18	.389		
	Total	8.808	19			
Magnesium	Between Groups	.186	1	.186	.506	.048
	Within Groups	6.625	18	.368		
	Total	6.812	19			
Potassium	Between Groups	.008	1	.008	.421	.525
	Within Groups	.342	18	.019		
	Total	.350	19			
Sodium	Between Groups	.711	1	.711	4.438	.049
	Within Groups	2.882	18	.160		
	Total	3.593	19			
Cations exchange	Between Groups	52.197	1	52.197	8.512	.009
	Within Groups	110.381	18	6.132		
	Total	162.578	19			
Available phosphorus	Between Groups	141.831	1	141.831	.205	.657
	Within Groups	12483.720	18	693.540		
	Total	12625.552	19			
organic matter	Between Groups	10.196	1	10.196	13.666	.002
	Within Groups	13.429	18	.746		
	Total	23.625	19			

Appendix 3

a) Air dried samples

b) Soil samples in separate zip lock plastic bags

c) Variety of fertilizers used by farmers who practiced mixed and mono-**cropping systems in Santa.**

d) Use of irrigation systems by farmers who practiced mixed and mono-cropping systems, channeling water to farms.

e) Use of animal droppings by mixed and mono-croppers as manure.

f): Mixed farm with several crops.

g: Some mono cropping farms

Appendix 4: Picture gallery

Appendix 5: Structured Questionnaire

Topic: An assessment of soil fertility status under mixed and mono-cropping systems: case of Santa, northwest region, Cameroon.

Dear respondent,

I am a master’s student from the Department of Development Studies, Pan African Institute for Development, West Africa Buea. I am carrying out a research on “A comparative study of changes in soil quality under Mixed and Mono-cropping systems, case of Santa, North West Region of Cameroon”. Your contribution will be very necessary for this research to be a success. Any information provided will be treated with absolute confidentiality. Your cooperation in this regard will be highly appreciated.

SECTION A: PERSONAL DATA

1. Farmer’s name ……………… Date…………….
2. Village……………………. ……………………………
3. Quarter ……………………………………………….
4. Sex: Male Female
5. Age: less than 20 20-35years 35-50years Greater than 50 years
6. Marital status: Married Single Widow Widower Divorced
7. Level of education: Primary Secondary High school University Professional Others…………………

SECTION B: FARMING DATA

8. What kind of cropping system do you practice? Mono-cropping Mixed cropping others …………………………….
9. Why do you practice this kind of cropping system? High productivity Less expensive It’s my culture less time-consuming others………………….
10. Are you the owner of the land on which you farm? Yes No
11. Where is your farm located? Level land Hilltop Slope valley Marshy or swamp land
12. If your farm is located on a slope, how do you do the farming? Along slope Across slope Make small mounds others specify……………………
13. What is your reason for farming? Consumption Commercial Both
14. How do you carry out the farming? Alone Employ workers Family labor
15. If you employ workers, what is your reason? Something else doing Due to your position in the community Too much farm work The need for high productivity
16. How do you prepare your farm for cultivation? Clear and burry residues with ground clear and later on burn the grass and till Clear just patches and plant Others…………

17. What kind of equipment do you use in cultivating?

Machetes	
Hoes	
Diggers	
Tractor	

18. What kind of crops do you grow?

Maize	
Sweet potatoes	
Irish potatoes	
Beans	
vegetables	
Carrot	
Green beans	
Green spices	
Cabbage	
Others	

19. How long have you been cultivating this /these crop(s)? Less than 5years 5-10 years 10-15 years 15-20 years More than 20 years
20. What is the rate of crop growth? Good Average Poor
21. What do you use in harvesting your crops? Machete Knives Gathering with hands
22. Do you integrate farming with animal rearing? Yes No
23. If yes, what kind of animal do you rear alongside farming? Cow Sheep Goat Pig Others specify………
24. If yes, how do you do it? Make paddocks for animals on the same farm land Make paddocks for animals away from the farmland others specify…………………………………..
25. Apart from farming do you carry out other activities? Yes No
26. If yes, what kind of activity? Business Teaching Driving Carpentry Others…………………………

SECTION C: SOIL FERTILITY ASSESSMENT

27. Soil type? Clay Sandy Loamy
28. Any local name for these soil? Yes No
29. If yes, what is the name?
30. What is the intensity of cultivation? Once a year Twice a year Seasonal More than twice

31. Have you noticed any change in fertility status in the last 5-10 years? Yes No
32. If yes, what parameters justify this? More compost/manure use Use of chemical fertilizers Irrigation Others……………………
33. How do you improve the fertility status of your farm?
Apply animal dung Apply chemical fertilizers Others……….
34. If you apply animal dung, what animal dung do you use? Cow dung Pig dung Fowl dung Goat others……………
35. If you apply chemical fertilizers, which fertilizers do you use and in what quantity? Fertilizers name ………….. Quantity (in kg)…………
36. Is the available manure adequate to your requirement? Yes No
37. Why do you use fertilizers? Training from workshops Poor nature of soils
38. Have you been trained on the use of fertilizers before? Yes No
39. Have you practiced this farming system before without fertilizers? Yes No
40. What do you think the productivity would look like if?

	Increase	Decrease	Remain stable	No idea
You don't use chemical fertilizers				
You don't use organic fertilizers				
You continue using chemical fertilizers				
You continue using organic fertilizers				
You stop using chemical fertilizers				
You stop using organic fertilizers				

41. Is your farm close to any river/stream? Yes No
42. Over the years, how would you estimate the intensity of rainfall? Increasing Decreasing Stable
43. Over the years, how would you estimate the intensity of sunshine? Increasing Decreasing Stable
44. In the course of farming, what kind of soil organisms do you see? Earthworm Centipede Millipede All
45. What soil particles dominate your farm? Fine texture Sandy Gravels Rocky others… …………..

Thank You