UNIVERSITY OF CAPE COAST

# STRATEGIES FOR SUSTAINABLE PRODUCTIVITY OF MAIZE (*ZEA MAYS* L.) - BASED FARMING SYSTEMS OF SMALLHOLDER FARMERS IN GHANA

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# STRATEGIES FOR SUSTAINABLE PRODUCTIVITY OF MAIZE (*ZEA MAYS* L.) - BASED FARMING SYSTEMS OF SMALLHOLDER FARMERS IN GHANA

BY

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Thesis submitted to the Department of Crop Science of the School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Doctor of Philosophy degree in Crop Science

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# DECLARATION

## Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:.................................................. Date:..........................

Esther Marfo-Ahenkora

## Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature:.................................... Date:.........................

Dr. Kingsley J. Taah

Co-Supervisor's Signature: .......................................... Date:.........................

Prof. Elvis Asare-Bediako

## ABSTRACT

Maize production in Ghana is limited by several factors including inadequate use of improved varieties and soil fertility amendments. Two on-farm experiments were conducted during the major and minor cropping seasons of 2017 in the Eastern and Central regions of Ghana in the semi-deciduous forest zone and coastal savannah zone respectively, to evaluate the effect of goat manure (5 t $ha^{-1}$), inorganic fertilizer (NPK; 250 kg $ha^{-1}$ + Urea; 125 kg $ha^{-1}$) and their combination on phenology, growth and yield of three maize varieties (Omankwa, Obatanpa, Ahomatea). Also investigated using focus group discussion and questionnaire were the factors influencing the adoption of sustainable maize production practices. Net benefit for introducing each treatment was evaluated using the partial budgeting approach. Application of the different soil amendments resulted in significant variations in growth and yield parameters for all the maize varieties with seasonal effects. The sole inorganic fertilizer produced significantly ($P < 0.001$) higher plant growth and grain yields in the major cropping season. Application of 50% inorganic fertilizer + 50% goat manure significantly ($P < 0.001$) out-performed either the goat manure alone, inorganic fertilizer alone or the control for all the varieties in the minor cropping season. Omankwa out-performed Obatanpa for grain yield and net benefit in the two agro-ecological zones (AEZ). This study has ascertained the use of improved maize varieties and appropriate soil fertility management as sustainable strategies in maize production and recommends the application of 50% inorganic fertilizer + 50% goat manure for sustainable maize production in smallholder farms in both AEZs. Adoption of sustainable maize production practices is however influenced by socio-cultural, socio economic, technical and biophysical factors.

# KEYWORDS

Agro-ecological zone

Farming systems

Goat manure

Inorganic fertilizer

Maize

Smallholder farmer

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# DEDICATION

This work is dedicated to my dear husband Kobby and our lovely children Maame Yeboaa, Paa Kwasi and Maabena. *Their Love, Sacrifices, Support, and Prayers Made All This Possible. To God be the glory!!!.*

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## LIST OF ACRONYMS

| | |
|---|---|
| ADRA | Adventist Relief Agency |
| AEZ | Agro-ecological zone |
| ANOVA | Analysis of variance |
| CIMMYT | International Maize and wheat Improvement centre |
| CSIR | Council for Scientific and Industrial Research |
| CSZ | Coastal savannah zone |
| FGD | Focus group discussions |
| FSS | Farmer saved seeds |
| FYM | Farm yard manure |
| GPS | Geographical positioning System |
| IFDC | International Fertilizer Development Centre |
| IFPRI | International Food Policy Research Institute |
| IITA | International Institute of Tropical Agriculture |
| KEEA | Komenda Edena Eguafo Abirem |
| MiDA | Millennium Development Authority |
| MoFA | Ministry of Food and Agriculture |
| NPK | Nitrogen Phosphorus Potassium |
| OPV | Open pollinated variety |

| | |
|---|---|
| PRA | Participatory rural appraisal |
| SDFZ | Semi-deciduous forest zone |
| SED | Standard error of the difference |
| SIP | Sustainable Intensification Practices |
| SSA | Sub-Sahara African |
| UNESCO | United Nations Education Scientific and Cultural Organization |
| WAAPP | West African Agricultural Productivity Programme |
| WAS | Weeks after sowing |

# CHAPTER ONE

# GENERAL INTRODUCTION

## 1.1. Background to the study

Maize (*Zea mays*. L) Is one of the most essential cereal worldwide alongside wheat and rice. It is grown throughout the world, although there are large differences in yields among countries (FAOSTAT, 2012). Globally, maize is grown on approximately 140 million hectares with developing countries cultivating approximately 96 million hectares (FAO, 2003). Maize is a primary food and cash crop for over 100 million people in Africa (Bosque-Perez, 2000). The crop is the most widely-grown staple food crop for an estimated 50% of the population in sub-Saharan Africa (SSA) occupying more than 33 million hectares of SSA's estimated 200 million hectares of cultivated land (FAOSTAT, 2010; Macauley, 2015). About 67% of the total maize production in the developing world comes from low and lower middle income countries and provides 50% of their basic calories (FAOSTAT, 2010; Atakora, 2011).

Maize is a versatile crop grown in all the agro-ecological zones in Ghana predominantly by smallholder resource-poor farmers under rain-fed conditions (MoFA, 2011; Fening et al., 2011). About 70% of the total maize produced in Ghana is by smallholder farmers (MoFA, 2013). Maize is the most extensively produced and consumed cereal crop, accounting for more than 50% of total cereal production in Ghana and its production has seen an increasing trend since 1965 (Morris et al., 1999; FAO, 2008; IFPRI, 2014) hence making it an important crop for the country's agricultural sector and for food security. An estimated net consumption of 1,285,335 Mt was recorded in 2015 (MoFA, 2016) and about 1,000,000 Mt of maize is reported to be marketed annually in

Ghana Darfour and Rosentrater (2016). Maize is also an important constituent of livestock and poultry feeds as well as a raw material for the brewing industry (Breisinger et al., 2011).

## 1.2. Statement of the problem

In spite of the economic importance of maize in Ghana, there is a deficit in the production of the crop due to its high demand. The annual domestic deficit for maize is estimated to be between 84,000 and 145,000 Mt representing a shortfall in domestic production of between 9 and 15 % of total human consumption (MoFA, 2009). The shortfall is projected to increase if pragmatic measures are not put in place to address the yield gap (MoFA, 2009).

Low yields of maize in Ghana are a major contributing factor to the production deficit of the crop. The average maize yield in Ghana is estimated to be 1.92 Mt ha$^{-1}$ (MoFA, 2016) much lower than the average for Africa south of the Sahara (3.5 Mt ha$^{-1}$). It is also lower than yields achieved in similar lowland rainfed, tropical environments in Thailand (4.5 Mt ha$^{-1}$) and southern Mexico (3.2 Mt ha$^{-1}$) (FAOSTAT, 2013). However, achievable yields based on on-farm and on-station trials in Ghana are between 4 t ha$^{-1}$ and 6 t ha$^{-1}$ (Kombiok et al., 2012; MoFA, 2013). These figures show a huge gap of about 50-70 % between actual and achievable maize yields.

The deficit of local production for humans and poultry feed is made up through imports (Codjoe 2007; Gage et al., 2012; FAO 2013). In 2015 alone, Ghana imported 75,000 Mt of maize (USDA, 2015) to supplement local production. Declining soil fertility, use of unimproved varieties and non-certified seeds are among the major constraints influencing maize production in smallholder farms. Most smallholder farmers have resorted to the use of local varieties and even where they use improved varieties, the seeds have been recycled for several years. These practices could contribute to the low yields that are being recorded (MoFA, 2016). Local varieties have recorded yield reductions ranging from 45 to 67% compared to open pollinated varieties (OPVs) (Kpotor, 2012). The appropriate usage of improved maize varieties is therefore paramount.

On smallholder farms, soil fertility decline has been recognised as one of the major biophysical constraints affecting agriculture, particularly nitrogen (N) and phosphorus (P) deficiencies (Mokwunye et al., 1996). In Ghana, the soils of the major maize growing areas have been reported to be low in organic carbon (< 1.5%), total nitrogen (< 0.2%), exchangeable potassium (< 100 mg/kg) and available phosphorus (< 10 mg/kg) (Benneh et al., 1990; Adu, 1995). Increasing population pressure has resulted in intensification of land use with a number of smallholder farmers practicing continuous cropping. The soil nutrients in the natural resource base are therefore dwindling faster than they are being replaced. Ofori and Kyei Baffour (2006) have reported that nutrients and organic matter in the soil have been depleted and crop yields have steadily decreased over the years. Globally, about 3.3% of agriculture GDP is lost annually as a result of soil and nutrient losses and the soil nutrient depletion rates in Ghana is estimated at 35 kg N $ha^{-1}$, 4 kg P $ha^{-1}$ and 20 kg K $ha^{-1}$ annually (Bationo et al., 2018). Inorganic fertilizers are expensive and out of the reach of resource-poor farmers even at subsidized rates in Ghana.

The traditional means of restoring fertility to the soil through the practice of shifting cultivation (extended fallow system) or land rotation is no longer sustainable due to pressure on agricultural lands. In order to sustain soil and maize productivity, it is necessary to explore alternative soil fertility replenishment strategies which are effective and affordable to smallholder farmers.

### 1.3. Justification

Increasing population, urbanization, and the growing poultry, livestock and fish sectors in Ghana have contributed to increased demand for maize and maize products. The shortfall in the production of the crop will adversely affect small income families who rely heavily on the staple crop for food as prices are likely to rise and this could threaten food security as maize is one of the food security crops in Ghana. Zingore et al., (2007) reported that, to counter growing food insecurity in SSA, there are renewed efforts to support the predominantly subsistence farmers to intensify crop production mainly by increasing the use of fertilizers and improved crop varieties. Zingore (2011) cautioned that, other options for managing soil fertility, such as manure, crop rotations, and improved fallows are most effective when strategically combined with fertilizer application. Improved maize varieties have been reported to be normally more responsive to fertilizer application than local varieties (Sallah & Twumasi-Afriyie, 1999). Replacement of local varieties with improved OPVs has generally produced 100% grain yield increases globally (Pixley et al., 2009).

Introduction of sustainable strategies such as improved maize varieties, soil fertility management and improved agronomic practices will therefore increase maize production and thereby alleviate poverty and improve socio-economic conditions of smallholder farmers. In addition, the increased yields will ensure maize availability to meet the high domestic demand including the poultry, livestock and brewery industries and most likely for export.

Considerable research on mineral fertilizer use on maize in Ghana has been conducted but there remain knowledge gaps in terms of growth and yield response to goat manure alone or in combination with inorganic fertilizer for some maize varieties as well as limited economic analysis of such practices.

Saïdou et al. (2004) observed that, in developing technologies for the smallholder farming systems, there is the need to understand the socio-economic factors that shape the complex smallholder environment so that this can be factored into the technology development process. It is therefore necessary to discuss (with farmers) and address these yield constraints in order to improve maize productivity.

The principal maize growing areas in Ghana are Brong-Ahafo, Eastern, Ashanti, Central and Northern regions (Amanor-Boadu, 2012; MoFA, 2016). A number of studies to improve maize yields have however been conducted in the Brong-Ahafo, Ashanti and Northern regions of Ghana as well as in the Guinea savannah, forest and forest-transition agro-ecological zones (; Adjei-Nsiah, 2006; Agyemang et al., 2013; Berchie et al., 2013; Kanton et al., 2016; Fosu-Mensah & Mensah, 2016).

This current study was focused in the coastal savannah agro-ecological zone of the Central region and the semi-deciduous forest agro-ecological zone of the Eastern region where research information on maize farming systems are limited.

## Research objectives

### General objective

The overall objective of the study was to develop sustainable strategies to increase productivity of maize-based farming systems of smallholder farmers in two agro-ecological zones of Ghana.

**The specific objectives were to:**

a) identify the socio-cultural, socio economic and biophysical factors that influence production of maize in maize-based farming systems in the semi deciduous forest and coastal savannah agro-ecological zones;

b) assess the performance of two improved maize varieties and one landrace (local variety) under different soil amendments in smallholder farms in the two agro-ecological zones;

c) evaluate the effect of minor season application of soil amendments and also residual effect of the different soil amendments on the growth and yield of maize in the minor season in two agro-ecological zones;

d) conduct economic analysis to assess the change in profitability of using inorganic fertilizer and/ or goat manure as soil amendments on three maize varieties in two agro-ecological zones .

## 1.4 Research questions

i. What socioeconomic, socio-cultural, technical and biophysical factors influence production of maize by smallholder farmers in the SDFZ and CSZ of Ghana?

ii. To what extent do improved maize varieties and organic/inorganic soil amendments increase maize productivity in the two agro-ecological zones?

iii. To what extent do residual and applied nutrients influence performance of improved maize varieties in the two agro-ecological zone in the minor season?

iv. What is the change in profitability of using different soil amendments on three maize varieties in two AEZ

## 1.5 Significance of the study

The research findings will provide farmers with a menu of appropriate soil fertility amendments and maize variety that will improve soil fertility and maize growth and yield. Thus, important information that is needed to enhance the smallholder farmers' decision making process in adopting improved maize variety and effective soil fertility measures will be provided. Farmers will then be able to decide whether it is cost-effective to devote more resources such as purchasing of improved maize seeds and use of other soil amendments in their farming operations.

Additionally, the findings from this study will assist policy makers in developing sound policy recommendations and effective implementation strategies to increase soil fertility and crop productivity. Finally, the research findings will assist the Ministry of Food and Agriculture (MoFA) in their quest for formulating appropriate organic and inorganic fertilizer schedules and recommending appropriate maize variety for similar agro ecological zones. This will ultimately lead to improved crop yields while maintaining environmental health in smallholder farming systems.

## 1.6 Delimitation

The study initially covered two districts in both the Semi-deciduous forest zone of the Eastern region and the Coastal savannah zone of the Central region. Subsequent experimentations were conducted in one district each because socioeconomic conditions within the specified agro ecological zone for the initial districts were the same. A number of maize varieties have been released in Ghana but the results from the socio economic study advised on the choice of three varieties. So two improved Open pollinated maize varieties (Omankwa and Obatanpa) and one landrace (Ahomatea) were used for this study.

## 1.7 Limitations

Plant nutrient analysis could have been done at different growth stages to determine nutrient uptake by the different varieties. Furthermore, soil physical and chemical analysis could have been done at the end of every season to determine the soil nutrient status before the minor season planting and also at the end of the minor season to assess the effect of the different soil amendments on soil properties but this was not done due to financial constraints.

## 1.8 Organisation of the study

The work has been organised into four main studies based on four specific objectives. Study one was a survey to determine the factors that influence adoption of improved and sustainable maize production technologies in two district in the Semi-deciduous forest (SDFZ) and Coastal savannah (CSZ) Agro-ecological zones. Study two investigated the performance of three maize varieties on four soil amendments in one district each in the SDFZ and CSZ in the major season. Study three investigated the effect of a minor season application of different soil amendment and residual effect of the amendments applied in the major season. Study four measured the profitability of using the different varieties as well as the different soil amendments in both the major and minor cropping seasons. One chapter was dedicated to general discussions, conclusions and recommendations.

## 1.9 Chapter summary

Maize production in Ghana is limited by several factors including inadequate use of improved varieties and lack/insufficient use of soil fertility amendments. This chapter highlights the background of the study and the statement of the problem citing relevant literature on work done on the study theme which led to formulation of the research questions, justification for the study as well as the research objectives.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1. Introduction

This chapter reviews relevant research and literature on issues pertaining to sustainable maize production and overall maize productivity in a smallholder farming environment. Maize is a food security crop in Ghana where its cultivation is mostly done by smallholder farmers.

There are quite a number of research works that have been conducted on socio-cultural circumstances of smallholder farmers as well as biophysical factors, agronomic practices and use of improved varieties that influence maize production and productivity. A summary of maize production trends, characteristics of smallholder farmers, biotic and abiotic factors influence maize production, and soil fertility management have been outlined in this chapter. Various research on maize variety development and overall sustainable production strategies for maize have also been discussed. Critical opinions revolving around the topics below are discussed in-depth by reviewing existing information and scholarly contributions to the subject matter.

Significant research works carried out have been reviewed under the following sub-themes:

- Maize production trends in Ghana
- Characteristics of smallholder farmers
    - Farming systems of smallholder farmers
    - Challenges of smallholder farming
    - Prospects of smallholder farming
- Biotic and abiotic factors influencing maize productivity

- Declining soil fertility and effects on maize production
- Approaches to soil fertility improvement
    - Fertilizer use in maize production systems
    - Manure use and prospects in maize farming
    - Integrated nutrient management in maize production
- Development and use of improved maize varieties
- Sustainable production strategies for maize

In the course of the review, gaps were identified that informed this research and added value to the experimental design and methods.

## 2.2. Maize production trends in Ghana.

Maize production plays a vital role in food security for many poor households in Ghana with a per capita consumption of over 45 kg per annum (MoFA, 2016) while also serving as a cash crop. One million metric tons of maize is reported to be marketed annually in Ghana (Darfour and Rosentrater, 2016). Acquah and Kyei. (2012) reported that maize production contributes over 20% of incomes earned by smallholder farmers in Ghana.

Maize cultivation in Ghana has been on-going since the late 16th century and got established as an essential staple crop in the southern part of Ghana after its introduction (Darfour & Rosentrater, 2016). Annual yields of maize have been reported to be growing around 1.1% with its production experiencing increasing trends since 1965 (Morris et al., 1999; IFPRI, 2014). The expansion of land assigned to maize cultivation increased production from 2.4 million Mt in 1961 to 10.6 million Mt in 2005 (FAO, 2006).

The area harvested for maize increased steadily from 750,000 Ha in 2005 to 1,042,083 Ha in 2012 and then there was a steady decline up to 2014 and a sharp decline to 883,031 Ha in 2016. Area harvested however started rising in 2017 to 1,000,000 Ha (FAOSTAT, 2019). Maize cultivation in Ghana has experienced dwindling yields over the years increasing steadily from 1.5 Mt ha$^{-1}$ in 2005, to about 2.0 Mt ha$^{-1}$ in 2017. Production quantities have also been on the increase from 1,171,000 Mt in 2005 to 2,011,179 Mt in 2017 with occasional decreases in production in 2011 and 2013 to 2016. Maize exports from Ghana have however declined over the years (2005-2017) from 12,073 Mt in 2007 to 3,975 Mt in 2017 (FAOSTAT, 2019). This may be attributed to relatively low production of the crop with maize being mostly consumed within the country. Imports have however been dwindling from 100,000 tons in 2006 to 40,661 in 2017 (FAOSTAT, 2019).

The current area planted to maize in Ghana stands at approximately one million hectares, with the yield and production averages of about 1.92 t ha$^{-1}$ and 1.69 million Mt respectively (MoFA, 2016) while the average yield of maize in developed countries can reach up to 9.86 t ha$^{-1}$ (Shiferaw et al., 2011) indicating that productivity is very low in Ghana despite the importance of maize in Ghanaian agriculture (MoFA, 2016).

Maize cropping systems and production technologies vary among the four major maize production agro-ecological zones (Morris et al., 2003). Maize cultivation in Ghana is mainly dependent on rainfall (Dankyi et al., 2005) resulting in high yield fluctuations mostly determined by rainfall variations. A large quantity of maize grains produced remains within households of producers as a primary staple food (Gage et al., 2012). Feed companies prefer yellow maize, which currently accounts for almost all maize imports (FAOSTAT, 2012).

## 2.3. Characteristics of smallholder farmers

Smallholder farming is the backbone of African agriculture and food security. Two-thirds of sub-Saharan Africa’s population that resides in the rural areas can be considered as smallholder farmers (Dixon et al., 2004). Their importance derives from their prevalence, their role in agricultural and economic development and the concentration of poverty in rural areas. Enhancing smallholder productivity is a practical and beneficial way to attain large scale food production and hence food security. In Ghana, smallholder farming characterised by low inputs forms the greater part of crop production (FAO, 2007). The term ‘smallholder’ refers to their limited resource endowments relative to other farmers in the sector (Dixon et al., 2004). Thus, the definition of smallholders differs between countries and between agro-ecological zones (Dixon et al., 2004).

Agriculture in Ghana is predominantly on a smallholder basis and majority of farm holdings are less than 2 hectares in size MoFA (2016). In Ghana, smallholder connotes farmers with limited land availability leading to smaller land holdings, resource poor so less prevalent use of inputs, low market orientation, relatively high degrees of vulnerability to risk and farm enterprises are primarily dependent upon family labour because of their limited capital (Chamberlin, 2007).

Dixon et al. reported that, in favourable areas with high population densities, smallholders often cultivate less than one hectare of land, whereas they may cultivate 10 hectares or more in semi-arid areas, or manage a herd of

10 livestock. They are also characterised by their allocation of resources to food, cash crops, livestock, off-farm activities, their use of external inputs and hired labour, the proportion of food crops which are sold and in their household expenditure pattern (Dixon et al., 2004). Generally, the character of the small scale farming sector comprises small farms that use traditional production techniques that are labour-intensive and lack institutional capacity and support (Greenberg, 2010).

Smallholders represent a large number of holdings in many developing countries and their numbers have increased in the last two decades. Evidence from the world census of agriculture for a small number of selected countries in Africa shows that between 1980 and 1990, the percentage of agricultural holdings of less than 1 ha had increased from 50% to about 78% (FAO, 1997). Smallholder rain-fed farming using rudimentary technologies dominates the agricultural sector accounting for 80% of total agricultural production. Approximately 90% of smallholder farms have less than two hectares in land size, and produce a diversity of crops (Wood, 2013).

Smallholders as a group, including the non-poor, still dominate most farming systems of developing countries and, on the positive side, account for a majority of rural employment, most food production and significant export earnings (Dixion et al., 2004). Dixion et al. (2004) reported that most smallholders have diverse sources of livelihood including significant off-farm income, yet are still vulnerable to economic and climatic shocks.

Waddington et al. (2004) characterize smallholder productivity as “low input–low output” farming. In reality the smallholder farmer category is a continuum of farm types ranging from subsistence to commercial. This means that a small-scale farmer might be resource-rich, resource-poor or somewhere in between, and could be involved in commercial production, semi-subsistence or subsistence production (Greenberg, 2010).

Crop production systems in many smallholder farm households are not environmentally sustainable due to nutrient mining and land degradation (Stoorvogel & Smaling, 1990; Gruhn et al., 1995). Most small-scale farmers do not have access to formal credit and therefore cannot afford to buy chemical fertilisers even where it has been demonstrated beyond doubt that it is profitable to do so (Obeng et al., 1990). The lack of fertiliser use has resulted in reduced food production and smaller farm incomes (Sanchez et al., 1997).

The efficiency levels of farmers in Ghana are very low due to limited access to credit which translates into low working capital, thus impeding their ability to purchase productivity enhancing-inputs such as improved seeds, fertilizers, weedicides and pesticides (World Bank Report, 2010). The aim of researchers should therefore be to offer farmers a wider range of effective but low-cost options, from which they can choose the best for a particular set of circumstances.

Practicality is also important: technologies must not be too labour or cash demanding, and must fit within the resources and capabilities of the majority of farmers (ICRISAT/MALI, 2000). Increasing productivity of the smallholder farmers, bridging the yield gaps by providing appropriate inputs along with improved technologies such as stress resistant and high yielding varieties and empowering farmers to better manage climate risk will be a step towards agricultural transformation in Africa (Macauley, 2015).

### 2.3.1. Farming systems of small holder farmers

Farming systems of smallholder farmers vary greatly across the globe and also within countries. Giller et al. (2011), studying various sites across SSA observed that there are trajectories of change in farming systems in response to population growth, economic conditions, climate variability and climate change. Giller et al. (2011) reported that the changes in farming systems seem to be driven principally by increasing population pressure and declining soil fertility. Although smallholder farms are regarded as stable systems, both farms and farming systems are moving targets and smallholder farming systems are highly dynamic (Giller et al. (2011). Traditionally in Ghana, a smallholder land owner uses land-fallow practices, a crop rotation system of farming and more recently continuous cropping.

Intercropping has long been a common practice in developing countries and is increasing among the small growers, because of their diversified needs and low farm income from the mono-cropping system (Wahla et al., 2009). Several attempts to improve the performance in intercropping systems have been made by planting cereal and cowpea at the same time and manipulating their row spacing and densities (Norman, 1975). Crop rotations, intercropping, sequential, strip, relay cropping systems, reduced tillage, legume cover crops, adding manure and compost and fallow techniques are all proven and available practices to farmers (Matata et al., 2001; Bationo et al., 2007; Ojiem et al., 2007; Maass et al., 2010). These practices make soils richer in organic matter, more able to hold soil moisture and reduce erosion.

Cereals being the most important food crops in Africa are in most cases intercropped with a minor/ companion crop for various reasons including as a complement in most local dishes (Rowhani et al., 2011). According to Carlson (2008), the advantages of intercropping include: reduced soil erosion and protection of topsoil, especially in contour strip cropping; attraction of beneficial insects especially when flowering crops are included to the intercropping system. Intercropping also lead to maximization of land productivity particularly in the high rainfall areas, increased total production and increased farm profitability (Carlson, 2008). lt has been suggested that intercropping, crop rotation, strip cropping and relay cropping can minimize crop-failure risks, reduce the adverse effects of pests and provide higher returns (Carlson, 2008; Geren et al., 2008; Deveikyte et al., 2009).

In parts of southern Ghana, maize is the first crop to be planted after the onset of the major season rains. For the smallholder farmers, the maize is sometimes intercropped with cassava 2-4 weeks after maize seedling emergence. Farmers who intend to replant maize in the minor cropping season on the same piece of land do not intercrop the maize with any other crop.

In spite of the numerous advantages of intercropping, there are some challenges associated with it. For instance, farmers find it difficult to use selective herbicides for weed control in maize-cassava intercrops. In addition, harvesting of maize in maize-cassava intercrop becomes more laborious because extra care is required in order not to break the tender stems of the cassava during maize harvesting. Also, crops to be used for intercropping if not chosen carefully, can lead to excessive mining of nutrients from the soil.

### 2.3.2. Challenges of smallholder farming

Smallholders are a diverse set of households and individuals who face various constraints on their ability to undertake potentially profitable activities in the agricultural sector. With increasing land constraints in most areas, fallow periods have drastically declined to a minimum level in most part of Africa (Kwesiga et al., 2003). Smallholder agriculture, which relies heavily upon the underlying agro-ecological (environmental) conditions that vary markedly over time and space affects productivity and efficiency in resource use as observed by Okike et al. (2004).

In most developing countries, fewer inputs are purchased for the cropping system and farmers depend essentially on the natural resource base. Additionally, due to their small scale of operation and poverty, these farmers lack the capacity to be able to adjust their farming systems to climate and land use shocks. Kisaka (2014) studying rainfall variability in two counties in Kenya indicated that, smallholder farmers are highly vulnerable to unpredictability of rainfall patterns and that they remain predisposed to increased crop failure as well as loss of alternative livelihood sources such as livestock.

Smallholder agriculture is still faced with many challenges and constraints to attain acceptable growth levels. However, a viable smallholder agricultural sector can be realized by ascertaining the specific constraints to its development with emphasis on institutional, technical and entrepreneurial factors (Oettle et al., 1998). Most smallholder farmers in Africa have limited access to land and capital and have received inadequate or inappropriate research and extension support resulting in low standards of living. In most parts of Africa, agricultural production is carried out within increasing pressure of scarce land resources managed under insecure customary land ownership (ECA, 2011). The vast majority of smallholders do not have formal title to the land they farm and that they may own the land through traditional structures, or they could be sharecroppers or renters (Foley et al., 2011).

Inappropriate postharvest handling of grain leads to an estimated 20% avoidable losses in the postharvest stages (Macauley, 2015). Saving half of this loss will make more efficient use of resources used for growing crops and add 10% more maize in African economy (Macauley, 2015). The scarcity of postharvest capacity and infrastructure among smallholders and the subsequent loss of output significantly limit smallholders' profit potential and participation in high-value markets (Shenggen et al., 2013).

More often than not, standardised technologies are disseminated to diverse groups of farmers. However, smallholders are not a homogeneous group, and development policies should not treat them as such. Technology development and adoption have often failed to recognise farmers as both a potential source of information about their production environments and cropping systems, and a source of innovation suitable for such environments (Richards, 1985; Hall and Clark, 1995).

### 2.3.3. Prospects of smallholder farming

Smallholders may benefit from the establishment of a production cooperative that integrates partially or totally their farming activities (Barton, 1989). This horizontal integration consists of a farmers' union that jointly plans and executes both biological and mechanical processes required for agricultural production under the coordination of a common governance body (Barton, 1989). Smallholder farmers can form a group that can serve as collateral to take credit from the formal credit sector (Yehuala, 2008).

The expansion of smallholder farming can lead to a faster rate of poverty alleviation, by raising the incomes of rural farmers and reducing food expenditure, and thus reducing income inequality (Kamara et al., 2003). Surveys of farms of different sizes in developing countries frequently show small farms producing more per hectare than large farms, which is an inverse relationship between farm size and production per unit of land (Cornia, 1985; Eastwood & Lipton, 2004).

Communication between farmers, researchers, and extension workers could be improved through on-farm demonstrations, farmer field schools and field days. Similarly, information and communication technologies (ICTs) can offer smallholder farmers a wealth of opportunities to acquire real-time market information on, for example, prices, demand, quality standards, and weather (Shenggen et al., 2013). Mobile phones can be used by farmers to communicate their challenges/ problems to extension personnel and get feedback. In this regard, the Ministry of Food and Agriculture in Ghana is implementing a programme called E-Agriculture Programme which is an ICT initiative through the West African Agriculture Productivity Programme (WAAPP), where farmers are given a code number they can call to access agricultural information in their local dialects (FAO, 2017).

Policies that promote climate change mitigation and adaptation in agriculture are especially useful for helping smallholder farmers manage risks while improving productivity (Shenggen et al., 2013). Since majority of smallholder farmers have low incomes, technical packages to increase and sustain agricultural production must be affordable, profitable and applicable to ensure its acceptability and adoption (Harris, 2002). Participatory research methods can guarantee farmers have a role in the formulation of recommendations, and reveal farmers' adaptive and adoptive responses to those recommendations and the impacts resulting from them (Sanginga, 2012).

## 2.4. Biotic and abiotic factors influencing maize productivity.

The ultimate yield of maize is reported to be controlled by a number of genetic and external factors (Ofori & Kyei-Baffour, 1993; Ahmed et al., 2001). Smallholder farmers are generally confronted with a number of biotic and abiotic stresses that are responsible for the low yields of their crops. Recurrent drought, low levels of fertilizer use, and low adoption of improved varieties all contribute to the low yields. It is clear that climate influences incidence of pests, diseases and weeds, though their intensities differ between crops and regions depending on climatic conditions, crop resistance and crop management such as cultivation techniques (Ofori & Kyei-Baffour, 1993).

### 2.4.1. Biotic factors influencing maize production

Diseases, insect-pests, weeds and parasitic plants can significantly reduce yields of crops in both temperate and tropical regions and have presented a continuous challenge to cereal productivity in SSA (Ofori & Kyei-Baffour, 1993). An estimated 54% of attainable yield is lost annually to diseases (16%), animals and insects (20%) and weeds (18%) in Africa (Shiferaw et al., 2011).

The problem of disease and pest control among different production levels is particularly acute for the small-scale, resource-poor systems under which maize is typically grown in SSA. Low yields in maize production in Ghana are partly due to heavy pre-and post-harvest losses caused byd diseases, weeds and pests (Ofori & Kyei-Baffour, 2006). Storage insect pests, mainly the maize weevil (*Sitophilus zea mais*), larger grain borer (LGB) (*Prostephanus* *truncatus*), angoumois grain moth (*Sitotroga cereallela*) and the lesser grain weevil (*Sitophilus oryzae*) cause an estimated 20–30% loss of maize, thus negatively impacting food security and income generation (Shiferaw et al., 2011). Minimizing such losses will significantly contribute to nutrition and food security in SSA.

Biotic stresses such as maize lethal necrosis (MLN), maize streak virus (MSV), Turcicum leaf blight (TLB), gray leaf spot (GLS), southern leaf rust, blight, stalk borers, and the parasitic weed *Striga hermonthica* are common in maize fields in SSA (Macauley, 2015). Ofori and Kyei-Baffour, (1993) suggested that diseases are best controlled through maize breeding programmes that develop hybrids/improved varieties with resistance to such diseases and proposed that, the most inexpensive control measure for insects is through crop rotation, which ensures that maize is not grown on the same land year after year.

It has been estimated that a 2 °C rise in temperature has the potential to increase the number of insect life cycles during the crop season by one to five times (Bale, 2002; Petzoldt & Seaman, 2005). This implies that, climate change has an influence on insect pest proliferation. More recently, the fall armyworm (FAW) has become one of the most devastating pests affecting maize production in Ghana. Research and extension efforts must therefore be doubled to bring this pest under control.

Numerous species of weeds can infest maize crops and cause yield losses in both temperate and tropical regions. Weed interference not only results in crop losses but also increases insect pest damage, harvesting difficulties and crop contamination (Ohene, 1998). Yield losses of up to about 40% have been reported in maize due to weeds (Oudejans, 1991). Maize is very susceptible to competition from weeds especially in the early stages of growth and is most sensitive to weed competition during the first month after sowing; therefore, efficient control at the pre- and early post-emergence stages is essential (Larbi & Anim-Okyere, 2016).

### 2.4.2. Abiotic factors influencing maize production

Abiotic stresses that undermine agricultural production and particularly maize production severely include the potentially adverse effects of drought, flooding, nutrient deficiency, and high and low temperatures (Shafiq-ur-Rehman et al., 2005). Climatic factors such as temperature, precipitation, moisture and pressure affect the development of plants, either alone or interacting with other factors (Cutforth et al., 2007). Global agriculture is facing the probable impact of global warming. Recent studies suggest that the production of major commodities has declined since 1980 due to global warming (Lobell et al., 2011). It is estimated that, given current warming trends in SSA, the production of major cereals could decline by as much as 20% by mid-century (Schlenker & Lobell, 2010).

The vulnerability of Ghana's agriculture to climate change is largely due to its dependence on rainfall (Yaro, 2010) particularly in the country's northern regions. As a result of the warming and changing climatic patterns, maize yield is going to be reduced especially among smallholder maize farmers, who may lack the resources to cope with these situations (Ofori & Kyei-Baffour, 1993). Drought and rainfall variability are some of the leading biophysical causes of food insecurity in SSA (TSBF, 2009). Drought has been identified as the most important constraint to enhancing maize production and productivity in the tropical and subtropical regions (Shiferaw et al., 2011) including Ghana

(Obeng-Antwi et al., 1999). Water stress can significantly impact number of leaves per plant at flowering, reduced plant height, as well as leaf area development (Cakir, 2004). While drought negatively affects all stages of maize growth and production, the reproductive stage, particularly between tassel emergence and early grain filling, is the most sensitive to drought stress (Grant et al., 1989). Drought stress during this period results in a significant reduction in grain yield, associated with a reduction in kernel size (Bolaños & Edmeades, 1993). High and significant correlations between maize yield and rainfall variability underpin the fact that rainfall is a prime yield determinant just like fertilizer use, and other farm inputs (Kisaka, 2014).

In Ghana, agricultural production is mainly rain-fed with the arable lands under irrigation being less than 2 % (MoFA, 2016). Rainfall however has seen a decline over Ghana since the 1970s and has only begun to increase slightly since 2006 (Owusu & Waylen, 2012; Lacombe et al., 2012). In order to maximize maize yields soil moisture should be maintained above 50% of the available water holding capacity in the rooting depth of the soil profile throughout the growing season (Ofori & Kyei-Baffour, 1993).

High temperatures experienced especially during tasseling /silking results in significant yield decreases (Southworth et al., 2000). Mera et al. (2006) showed that unlike temperatures which have a non-linear effect on yields, rainfall has a linear effect on yields. Schlenker and Lobell (2010); Epule and Bryant (2015) however argued that changes in temperature has stronger effects on maize production than changes in precipitation. High temperature during the early stages of kernel development has been reported to also have a detrimental effect on kernel development and final kernel mass (Jones et al., 1984).

Since climatic factors are difficult to manipulate and Ghana's agriculture is mainly rain-fed, it would be prudent to concentrate efforts on improving soil fertility as well as using improved varieties to increase maize productivity. Research has produced drought tolerant varieties to combat the effects of drought. However, farmers' adoption level is still low (Ragasa et al., 2013). The use of drought tolerant crop varieties becomes imperative under such unpredictable weather conditions. Improved agronomic management can also improve soil quality and make cropping systems more resilient to changing environmental conditions

## 2.5. Declining soil fertility and effects on maize production.

Soil-fertility depletion in smallholder farms is the primary biophysical cause for declining per capita food production and food security in sub-Saharan Africa (Badiane & Delgado, 1995 ; Sanchez et al., 1997) and is also a major factor challenging crop production in Ghana (Logah et al., 2010).

In the sub-humid and semi-arid zones of West Africa, the most important constraint to food production in the predominantly smallholder crop-livestock farming system is continuous cropping and cultivation on marginal lands due to the scarcity of arable land (Saïdou et al., 2003). Zingore (2011) also reported that, problems of declining soil fertility are widespread in SSA, largely as a consequence of continued cultivation of crops with low levels of nutrient inputs. In most SSA countries, there is limited potential for increasing the area under cultivation due to rapid population growth. In addition, low external input agriculture, rapid decline in soil fertility due to the inherent low soil fertility and shortened fallow periods, have resulted in nutrient mining in the zone causing soil degradation (Smaling et al., 1997). Severe land degradation in SSA has threatened the agricultural productivity of smallholder farmers thereby hindering efforts to reduce poverty (Lufumpa, 2005). Moreover, poor agricultural management practices over many decades have contributed to a severe decline in the productive capacity of the soils (Sanchez, 2002).

Despite the overall patterns of soil fertility depletion, smallholder farms in SSA exhibit a high degree of soil fertility variability, and as a consequence, crop yields and yield responses to applied nutrients vary considerably between fields (Zingore et al., 2007; Tittonell et al., 2005).

Inorganic fertilizers are expensive and out of the means of many smallholder farmers. This has resulted in low fertilizer use, reduced food production and smaller farm incomes (Sanchez et al., 1997). Additionally, fertilizer-use efficiency is often low because of the declining level of organic matter in tropical soils (Kumwenda et al., 1996). Soil organic matter is an important additive in soils that helps balance soil microflora, soil moisture retention and helps improve soil structure.

Stoorvogel and Smaling (1990) reported that on the average, 660 kg N ha$^{-1}$, 75 kg P ha$^{-1}$ and 450 kg K ha$^{-1}$ have been lost in the last 30 years from about 200 million hectares of cultivated lands in 37 countries in SSA, excluding South Africa. It was estimated that annual net nutrient depletion exceeded 30 kg nitrogen (N) and 20 kg potassium (K) per hectare of arable land in Ethiopia, Kenya, Malawi, Nigeria, Rwanda, and Zimbabwe (Smaling, 1993; Stoorvogel, Smaling, & Janssen, 1993). FAO reports that there is a negative nutrient balance of approximately 27 kg N ha$^{-1}$, 4 kg P ha$^{-1}$ and 21 kg K ha$^{-1}$ annually in

Ghana (FAO, 2004). The main determinant of Africa's position at the bottom of the development scale is the need to tackle soil fertility depletion as the fundamental constraint (Sanchez et al., 1997). If the nutrient removal rates by crops are not timely balanced through soil amendments aimed at maintaining soil fertility, the soil will get poorer and productivity will reduce further (Logah, 2009).

A greater negative influence on maize yield has been the loss of soil fertility especially in wetter areas where yield potential is higher and insufficient use of fertilizers results in severe nutrient depletion of soils (Gladwin et al., 2002). The soils of the major maize growing areas in Ghana as well as the sub humid zone of Ghana are inherently low in plant nutrients and have been reported to be low in organic carbon (<1.5 %), total nitrogen (< 0.2 %), exchangeable potassium (<100 mg/kg) and available phosphorus (< 10 mg/kg) (Benneh et al., 1990 ; Adu, 1995; Abunyewa et al., 2007). The need for other sources of plant nutrients to augment these soils for increased maize productivity is therefore paramount.

The responsibility is on researchers, agricultural extension agents and farmers to make more dynamic effort to solve the extensive decline in soil fertility otherwise there will be a reduction in productivity of maize-based farming systems and improved maize germplasm will have only a transient effect on productivity in smallholders' fields.

## 2.6. Soil and nutrient requirements for maize

Maize is a very high nutrient–demanding crop, requiring adequate nutrition for maximum performance (Rashid & Ryan, 2004). The plant produces high dry matter yields and therefore has a high requirement for nutrients especially nitrogen (N), phosphorus (P) and potassium (K.) These nutrients are very essential for good vegetative growth and grain development in maize production. Maize also requires some other macro nutrients such as sulphur and magnesium which are constituents of protein and together with nitrogen are essential in chlorophyll used for photosynthesis (Bromley, 2011).

Maize thrives in well drained sandy loam soil with a pH of 5.7-7.5 and minimum of 500-800 mm of rainfall evenly distributed throughout the growing season for good yields (Atakora, 2011). The most suitable soil for maize is one with a good topsoil depth, favourable soil physical properties, well drained, and an optimal moisture regime with adequate and balanced amounts of plant nutrients (Bell et al., 2005). Many studies have shown that application of inorganic and or organic fertilizers increases plant growth mainly because they contain considerable quantities of plant nutrients, including micro nutrients which have high benefits for plant growth (Ibeawuchi et al ., 2006).

## 2.7. Approaches to soil fertility improvement

Crop agriculture is a soil-based industry that extracts nutrients from the soil. Therefore, effective and efficient approaches to slowing nutrients removal and returning of nutrients to the soil will be required in order to maintain and increase crop productivity and sustain agriculture in the long term (Gruhn et al., 2000). Soil fertility maintenance has been identified as the most important constraint to sustained yields under short fallow or continuous cropping systems in West Africa. A major contributory factor is the inability of resource poor farmers to purchase and use recommended chemical fertilizers in their production systems. The need to improve productivity of soils for increased production with less expensive and sustainable means is therefore paramount.

A number of soil fertility enhancement technologies have been proposed by various researchers in Ghana (Fosu-Mensah et al., 2004; Abunyewa and Karbo 2005; Adjei Nsiah, 2006; Adu-Gyamfi et al., 2007; Kombiok et al., 2012). There have however been challenges to the adoption of some of these soil fertility enhancement practices. These challenges include issues of land tenure, socio-cultural/socio-economic issues, inadequate financial resources as well as lack of appreciation of improved production technologies on the part of the farmers (Adjei Nsiah, 2006).

A better understanding of soil fertility variability and farmers’ resource use strategies is required for targeting soil fertility improving technologies to different niches. (Zingore et al., 2007).

Soil fertility management according to Vanlauwe et al. (2006) is usually related to access to resources, history of local farming, access to markets and agricultural policy. In this regard, efficient nutrient management, including the use of animal manure to recycle nutrients, the appropriate use of mineral fertilizers in cereal rotation and intercropping with dual purpose legumes are important options for soil fertility improvement.

### 2.7.1. Inorganic fertilizer usage in maize production systems

The principal aim of applying inorganic fertilizer is to increase crop productivity by improving soil fertility. Inorganic fertilizer use is recommended as a means of resolving the poor soil fertility problems in SSA (McIntire & Powell, 1995; Sanchez et al., 1997). Fertilizers have been reported to often double or even triple crop yields worldwide (FAO, 2000). It has been estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers (Stewart et al., 2005; Vlek, 1990). Fertilizer not only improves crop yields but it also increases the quantity of available crop residues useful as livestock feed or organic inputs to the soil (Bationo et al., 2004).

The availability of sufficient growth nutrients from inorganic fertilizers leads to improved cell activities, enhanced cell multiplication and enlargement and luxuriant growth (Fashina et al., 2002). Obi et al. (2005) reported that, luxuriant growth resulting from fertilizer application leads to larger dry matter production owing to better utilization of solar radiation and more nutrients (Saeed et al., 2001). Adediran et al. (2004) made similar observations when they reported that, the greater yield increase from the mineral fertilizer during the first cropping cycle might be due to its ability to make nutrients more readily available to crop plants. According to Lungu and Dynoodt (2008), one of the ways of addressing the impact of soil mining is the use of inorganic fertilizers.

However, use of these inputs among smallholder farmers is currently very low. Majority of smallholder farmers in SSA cannot afford mineral fertilizers. Though these smallholder farmers appreciate the value of fertilizers, they rarely apply them and even if they do, they hardly use the recommended rates at the appropriate time because of high costs and low variable returns (Phiri, 2005; Mugwe et al., 2009). ICRISAT (2006) reported that, there is the need to improve fertilizer use efficiency so that mineral fertilizer use is financially attractive to farmers. The value- cost ratio for fertilizer application on maize, a rough measure of the profitability of using fertilizer, is much higher in Ghana than in other countries (Jayne & Rashid, 2013). However, increasing dependence on chemical fertilizers and the continuous loss of organic matter in the soil may lead to a declining maize fertilizer response, as other countries have experienced (Jayne & Rashid, 2013).

Cereal yields in Africa are lower than half the world average and the average fertilizer (N + $P_2O_5$) consumption is 16.24 kg ha$^{-1}$ (FAO, 2010) and this is one-sixth compared to the world consumption of 98.20 kg ha$^{-1}$ (Macauley, 2015). Sanchez et al. (1997) observed that fertilizer use has been responsible for a large part of sustained increases in per capita food production that have occurred in Asia, Latin America, and southern Africa. Fertilizer use in Africa however, is by far the lowest of any developing region for various reasons including non-availability and high cost (Fosu et al., 2004).

Fertilizer application in Ghana is approximately 8 kg ha$^{-1}$ (FAO, 2005) while depletion rates range from about 40 to 60 kg of nitrogen, phosphorus, and potassium (NPK) ha$^{-1}$ yr$^{-1}$ (FAO, 2005). Ghana has seen some fluctuations in fertilizer usage, but the rates have always remained relatively low (FAO, 2005). As of 2010, fertilizer use in Ghana was well below the average in SSA at less than 6 kg ha$^{-1}$ (FAOSTAT, 2014). International Fertilizer Development Centre (IFDC) (2012) also reported that fertilizer use in Ghana is about 7.2 kg ha$^{-1}$, similar to the average rate in SSA, but significantly lower than in other developing countries despite agriculture’s importance to the overall economy of Ghana. In 2008, Ghana’s fertilizer subsidy policy reduced the price of fertilizer by 50%, yet even at those prices some farmers claimed that the subsidized fertilizer was not affordable (Yawson et al., 2010).

Fertilizer application rates are relatively low for all crops, but the average rate is slightly higher on maize fields (14 kg ha$^{-1}$) which accounts for about 64% of total fertilizer use (Heisey and Mwangi, 1997; Kherallah et al., 2002). Maize responds well to phosphate and nitrogen fertilizers, particularly where sufficient organic matter is also made available (Ker, 1995). However, maize yields vary depending upon variety, location, soil nutrient status and application of fertilizers. A study carried out in western Kenya reported 63% increase in maize yields using mineral fertilizers (Ayuke et al., 2004). A meta-analysis of fertilizer response under agroforestry in smallholder farming systems showed that fertilizers give a better maize yield response than legume trees and green manures (Sileshi et al., 2008). Oad et al. (2004) however reported that continuous use of fertilizers creates potential polluting effect in the environment.

Although fertilizer use is needed to maintain soil productivity, it must always be in conjunction with management practices that help maintain soil organic matter, such as the return of crop residue or other organic materials and minimum tillage (Franzluebbers et al., 1998).

### 2.7.2. Manure use and prospects in maize farming

Tropical soils are generally low in organic matter (Scheer, 1999) and the need to add organic matter to the soil to improve or at least maintain soil quality is an important concept in tropical farming systems (Subbain et al., 2000). Application of manure or composted manure can result in increased soil concentrations of nutrients and organic matter (Chang et al., 1991; Eghball, 2002). According to Mokwunye et al. (1996), manure improves soil organic matter (SOM) which is an important source of plant nutrients. Increasing the SOM content of soil is the key to building soil N capital (Buresh & Giller, 1998). Organic manure improves soil fertility by also influencing its physical, chemical and biological properties (Sweeten & Mathers, 1985; Bationo and Mokwunye 1992; Quansah 2010). It improves water circulation and soil aeration, and increases the soil moisture holding capacity (Soltner, 1985).

Most farmers in the savannah zone of West Africa keep livestock besides crop farming (Tarawali et al., 2004). Livestock especially small ruminants are also associated with crop farming in southern Ghana. Manure from these animals could therefore serves as one of the potential sources of soil organic matter and plant nutrients in these areas.

Harris (2002) observed that, manure when applied, will be mineralized gradually and nutrients become available but cautioned that, the nutrient content of manure varies, and the reason is that the fertilizer value of manure is greatly affected by the diet of the livestock, amount of bedding, storage and application methods.

Abunyewa and Karbo (2005) reported that, though the use of animal manure in crop-livestock farming system could improve soil fertility and increase crop production, animal residues are poorly managed. It has been reported that in Mozambique, less than 7% of smallholder farmers owning cattle use cattle manure as an amendment for crop production (SIMA, 2008 ; World Bank, 2006). Many studies have demonstrated that application of manure will produce crop yields equivalent or superior to those obtained with chemical fertilizers (Xie & MacKenzie, 1986; Motavalli et al., 1989). They reported that organic matter, total N and micronutrient content of the surface soil are increased as a result of manure application.

Zhang et al. (1998) found that 2 kg manure-N was equivalent to 1 kg of urea-N in terms of plant uptake and yield response during the first year following cattle feedlot manure application. In comparing organic fertilizers with inorganic fertilizers, study results are mixed. Kihanda et al. (2004) found that, over a seven year trial, Kenyan maize yields were similar in plots treated with goat manure to plots treated with inorganic fertilizer. However, studies by Mallory and Griffin (2007) found that inorganic N applications become available to crops more quickly than N applications from manure. Asibuo and Osei-Bonsu (2002) reported significantly high maize yields (5000 kg ha$^{-1}$) on treatments with manure and incorporated *Mucuna pruriens* compared to yields (1674 kg ha$^{-1}$) under control treatments.

Mureithi et al. (1996) reported that manuring increases yields of maize grain and stover. Amujoyegbe et al. (2007) also reported that poultry manure increases the leaf area, total chlorophyll content and grain yield of maize and sorghum. Similarly, Boateng et al. (2006) reported that poultry manure at a rate of 4 t ha$^{-1}$ improved maize yields significantly over the control. Uwah and Eyo (2014) observed that goat manure increased yields of sweet maize in Nigeria then Bala and Manga (2009) made similar observation working on cabbage as well as Nweke et al. (2013) who worked on okra. Growth and yield parameters of pepper were significantly increased by goat manure treatments (Awodun et al., 2007). Furthermore, Ojeniyi and Adegboyega (2003) found that goat manure increaseed growth of celosia whiles Odiete et al. (1999) reported that goat manure increased yield of okra, amaranthus and maize in southwest Nigeria.

### 2.7.3. Integrated Nutrient Management

Emerging evidence indicates that integrated soil fertility management (ISFM) involving the judicious use of combinations of organic and inorganic resources are a feasible approach to overcome soil fertility constraints within the smallholder farms (Zingore, 2011). Combining organic nutrient resources and mineral fertilizers has been shown to result in synergy and improved synchronization of nutrient release and uptake by crops (Palm et al., 1997). In recent years the focus of soil fertility research has been shifted towards the combined application of organic matter and fertilizers as a way to arrest the on-going soil fertility decline in SSA (Vanlauwe et al., 2001). Most farmers have little or no knowledge on the importance of integrating both organic manure and inorganic fertilizers to enhance yields. Some farmers are not aware that combining inorganic and organic fertilizer has been proven to replenish soils and even achieve better yields than either sole applications (Mucheru-Muna et al., 2007).

The combined applications of poultry manure with mineral fertilizer at a rate of 60 kg ha$^{-1}$ N produce yields, which are significantly higher than organic or inorganic alone and the control (Quansah, 2010). Studies carried out in southwest Nigeria, recommended combinations of farmyard manure (FYM) and NPK fertilizer for sole and intercropped maize in order to achieve maximum yields (Eneji et al., 1997; Ojeniyi &Adeniyan, 1999). For instance, at Uyole in Tanzania, application of low rates of NP fertilizers with FYM produced 7.10 t ha$^{-1}$ of maize grain compared to 4.03 t ha$^{-1}$ when the same rates of NP were used alone (Lyimo & Temu, 1992). Mishra (1993) and El-kholy and Gomaa (2000) succeeded in reducing the recommended rate of chemical fertilizer without loss in the yield of maize using about 50 % of chemical fertilizer in combination with 50 % bio-fertilizers.

Several studies have shown significant increase in soil productivity and crop yields when a combination of organic and mineral fertilizers was applied compared with sole application of organic or mineral fertilizer alone (Boateng & Oppong, 1995; Quansah et al., 1998; Murwira et al., 2001; Satyajeet et al., 2007). Sanginga (2012) confirmed that indeed, combining mineral and organic inputs results in greater benefits than either input alone, through positive interactions on soil biological, chemical and physical properties. Ojeniyi (2002) reports that nearly all attempts to maintain continuous crop production with chemical fertilizers alone in the tropics have failed and Adepetu (1997) concludes that combined use of organic and inorganic fertilizers is required for sustainable soil productivity under intensive continuous cultivation in Nigeria. Generally, chemical fertilizers provide short term results as compared to organic manures which are variable in their nutrient content (Chen 2006).

Residual effects of manure or compost application can maintain crop yield level for several years after manure or compost application ceases since only a fraction of the N and other nutrients in manure or compost become available to the plant in the first year after application (Motavalli et al., 1989; Ramamurthy & Shivashankar, 1996; Eghball, 2002). Ginting et al., (2003) also confirmed that, residual effects of organic materials on soil properties can contribute to improvement in soil quality for several years after application ceases Cooke (1970) cited by Quansah (2010), reported that farmyard manure and fertilizers from previous applications, leaves residues of nitrogen, phosphorus and potassium in the soil that benefit following crops and that the residues of inorganic nitrogen fertilizers usually last only for a season.

The effects of mineral fertilizer in combination with organic fertilization on crop growth, development, yields and soil fertility will depend on the source of organic material, the handling and storage of manure, the application rates of both organic and mineral fertilizers (Harris, 2002) as well as the nature of chemical fertilizers used. Strategically targeting fertilizer use to variable soil fertility conditions, combined with recycling crop residues, manure application, and various legume-based technologies is necessary for viable fertilizer use in smallholder farming systems in SSA (Giller et al., 2006).

## 2.8. Development and use of improved maize varieties in Ghana

The mandate and motivation of maize breeders in Ghana has essentially been to develop high and stable yielding maize varieties that will perform well in all the agro-ecologies in Ghana (GGDP, 1986). In furtherance of this, twenty-seven (27) improved maize varieties have been released since the 1960s (Ragasa et al., 2013). Varietal improvement and testing is mainly done by CSIR-Crop Research Institute (CRI) and CSIR-Savannah Agricultural Research Institute (SARI). Maize breeding efforts in Ghana intensified in 1979 with the beginning of the Ghana/CIDA Grains Development Project (Sallah, 1986). During the period of the project, the maize improvement programme developed and released white and yellow varieties with various maturity periods ranging from 80 to 120 days to suit the different agro-ecological zones of Ghana. Majority of the recent germplasm used by breeders in improvement programmes came from the International Maize and Wheat Improvement Center (CIMMYT) in Mexico and International Institute for Tropical Agriculture (IITA) in Nigeria while CRI and SARI scientists conducted genetic improvements (Ragasa et al., 2013).

Kpotor (2012) and Ewool et al. (2016) reported that, open pollinated varieties (OPVs) are high yielding than local varieties. Ragasa et al. (2014) observed in a survey that, although 61% of the maize area was planted with modern varieties, only 15% was planted with certified seed in Ghana About 80% of the seed used in the country is sourced from the informal sector, which entails farmer-saved seed, seed exchanges among farmers and purchases from local grain or seed markets (MoFA, 2015). The assertion is that although the research system has been very active in developing and releasing varieties, a very high weighted-average varietal age (23 years) in Ghana signals that either the research system produces many unneeded varieties that are not solving farmers' binding constraints or the agricultural extension system is unable to disseminate and educate farmers about the net benefits of improved newer varieties (Ragasa et al., 2014).

Etwire et al. (2013) reported that although, maize seeds account for most of the sales of certified seeds, there is a low volume of trade in certified seeds, and a large proportion of farmers depend upon informal sources for seed even though econometric results from a survey of maize fields show that plots planted with certified seed on soil amended with fertilizer had higher yields than plots planted with uncertified seeds (Ragasa et al., 2014).

Odendo et al. (2001) reported that nearly 80% of the farmers in Africa predominantly grow local maize varieties because of many reasons (such as ability to recycle seeds for many seasons, ease of storage, high flour-to-grain ratio and good taste), whilst about 20% grow improved varieties, often in addition to the local varieties. Also, most farmers prefer local varieties because they are perceived to be able to survive despite the odds of harsh environment, pest infestations and low soil fertility (Odendo et al., 2001).

Obatanpa, a quality protein maize developed through the GGDP project and released in 1992, has become very popular in Ghana and in other SSA countries (Ragasa et al., 2013). Obatanpa has even increased in popularity over the years (from 16% adoption in 1997 to 40% in 2013), while the newer varieties released by CSIR accounted for only 1% of the total area planted with maize according to the survey by Ragasa et al. (2013). The continuing popularity of Obatanpa among farmers in Ghana is due to its higher yield compared to the newer varieties (Ragasa et al., 2013). Also, in Ghana, the level of awareness and adoption of new varieties appear to be low. For instance, Omankwa an early maturing variety which is drought/striga tolerant is yet to be popular among farmers most probably due to a limited availability of its certified seeds at the local agro-input shops and also lack of knowledge on its existence by farmers and some extension agents. Langyintuo et al. (2010) confirmed that the major bottlenecks in the seed industry were lack of awareness of the availability and value of existing varieties, the high relative price of seed because of poor and uncompetitive grain prices and lack of credit.

## 2.9. Sustainable production strategies for maize

Agricultural productivity in Ghana must be increased to meet the demands of an increasing urban population, and to support sustainable rural livelihoods (Andriesse et al., 2007). Ghana’s population as at 2015 was estimated to be about 28 million with a population growth rate of 2.3% (MoFA, 2016). Efforts in increasing crops and livestock production must therefore be doubled to meet the nutritional requirements of this growing population. The demand for more food caused by an increasing population, however, has to be met in a sustainable manner. Achieving food security in sub-Saharan Africa (SSA) for a rapidly expanding population will require intensification of food production on existing croplands through enhanced nutrient inputs. Thus, a sustainable crop production system must adopt an integrated nutrient management strategy using balanced organic, biological and chemical nutrient inputs (Franzluebbers et al., 1998). In this thesis, sustainable maize production is the integrated use of improved maize varieties, improved agronomic practices and soil fertility improvements using organic and/or inorganic fertilizer.

Sustainable production offers a robust solution; in that the emphasis is not only on higher yields and production and more nutritious foods, but also more selective use of inputs, reduced adverse environmental impact, building resilience, and improvements in natural capital (Juma et al., 2013). A new paradigm for African agriculture has been advocated for, one that can help address food and nutrition insecurity as well as spur growth, reduce poverty and protect the continent’s natural resources (Juma et al., 2013).

The adoption of Sustainable Agricultural Practices (SAP) aimed at addressing the negative impacts of climate change on agricultural productivity, especially in semi-arid regions has become more crucial than ever (Crentsil, 2004). It has been reported that in Ghana, there are indicators that the level of adoption of SAP is low and that extension agents do not have adequate capacity to assist farmers to adopt the practices (Crentsil, 2004).

Sustainable intensification practices (SIP) in maize-based cropping systems such as integration of improved germplasm, improved agronomic practices, soil fertility improvement, water management, improved weed management and enabling policies are key determinants of improved crop productivity (Macauley, 2015). Jama and Pizarro (2008) also observed that, soil fertility improvement, improved seeds, good agronomic practices, access to credit, improved extension service delivery, market access, water management and improvements in weather forecasting are strategies that will improve and sustain smallholder production systems.

# CHAPTER THREE

# FACTORS INFLUENCING SUSTAINABLE MAIZE PRODUCTION IN SMALLHOLDER FARMING SYSTEMS IN THE SEMI-DECIDUOUS FOREST AND COASTAL SAVANNAH AGRO-ECOLOGICAL ZONES OF GHANA.

## 3.1. Introduction

Maize is a major source of food and income to many smallholder farmers in developing countries (Tagne et al., 2008). It is becoming increasingly important as a food security crop in Ghana because it provides ready cash and food for farm families. Maize production contributes over 20% of incomes earned by smallholder farmers in Ghana (Acquah & Kyei, 2012). Therefore, improving the productivity of the crop will enhance food self-sufficiency among rural households in most agro-ecologies. The smallholder production systems are however plagued with a lot of challenges including climate variability, poor soils, low yields, land tenure issues and lack of essential inputs such as improved seeds and fertilizers. As a result, greater emphasis needs to be placed on improving smallholders’ productivity through introduction of sustainable strategies such as improved maize varieties, appropriate soil fertility management and improved agronomic practices.

Sterk et al. (2013) reported that technology development alone cannot expand smallholders’ opportunities significantly and that within the means available to them, they could realise only marginal improvements and the farmers quickly stop using any technologies whose effectiveness require conditions that are beyond their means or control. It has been suggested that in developing technology for the smallholder farming systems, there is the need to understand the socio-cultural and socio-economic issues that underlies the intricacies of the smallholder environment so that this can be factored into the technology development and dissemination process (Saïdou et al., 2004). Experimenting with an interactive approach with farmers (bottom-up approach) to tackle the problem of low maize yields is one sure way to get farmers to readily adopt positive outcomes of the research.

It is important to analyse constraints (diagnostic study) and develop sustainable strategies through an experiential approach. Diagnostic studies allow in-depth investigation of socio-cultural, socio-economic, institutional and technical constraints as well as opportunities in a given environment. The aim is to understand the issues from the perspective of the smallholders (Roling et al., 2004). This is essential for formulating relevant research questions and selecting entry points for effective intervention. However, before any alternative options are developed, it is necessary to explore the potential to improve upon the existing options currently being used by farmers (Adjei-Nsiah et al., 2012). An attempt to discover the reasons for low technology adoption among maize farmers requires that the factors that influence their decisions to use or not to use sustainable practices be identified. CIMMYT (1988) reported that for on farm research, the first step should be diagnosis, if recommendations are to be oriented to farmers.

### 3.2. Objective

The objective of this study was to identify the socio-cultural, socioeconomic, technical as well as biophysical factors that influence maize productivity in smallholder farming systems in the semi–deciduous forest and coastal savannah agro-ecological zones.

## 3.3. Methodology

### 3.3.1. Selection of locations for the study

This research was conducted in the coastal savannah agro-ecological zone (CSZ) in the Central region and the semi deciduous forest agro-ecological zone (SDFZ) in the Eastern region of Ghana. A multistage sampling approach was used in selecting the locations for the study. A Multistage sampling is the taking of samples in stages using smaller sampling units at each stage. It contains two or more stages in sample selection. In this study, sample selection was done from the regions to the districts and to the communities. Multistage sampling with simple random sampling is where the researcher chooses the samples randomly at each stage.

The regional department of Agriculture offices of these two regions were contacted for the best six maize producing districts in each region. A simple random sampling was adopted to select two districts from each region. The Directors of agriculture of the selected districts were contacted for the best 10 maize producing communities. A simple random sampling was again adopted to select three communities per district.

With the help of the Agricultural Extension Agents (AEAs), some maize farmers and opinion leaders were purposively selected from each community for the focus group discussions (FGD). The two districts selected from the Eastern region were Upper Manya Krobo and Akuapem North districts representing the SDFZ, and Awutu Senya and Komenda-Edina-Eguafo-Abirem (KEEA) districts from the Central region representing the CSZ.

The three communities selected from each district were basically farming communities where most of the inhabitants were smallholder farmers. The communities selected for the study and their geographical locations are shown in Table 3.1.

**Table 3.1: Agro- ecological zones, districts, and communities selected for the study and their locations (GPS)**

| Agro-ecological zone | District | Community | Location (GPS) |
|---|---|---|---|
| Semi-deciduous forest zone | Akuapem North Municipal | Otareso/ Mankrado | 6°0'299"N<br>0°8'87.7"W |
| | | Okyerekrom | 6°3'916"N<br>0°8'436"W |
| | | Ahenkorase | 5°56'39.9"N<br>0°12'77.0"W |
| | Upper Manya Krobo | Akateng Manya | 6°30'10.2"N<br>0°8'36.5"W |
| | | Dzomoa | 6°20'56.4"N<br>0°8'35.3"W |
| | | Mensah Dawa | 6°19'11.4"N<br>0°7'53.1"W |
| Coastal savannah zone | Awutu Senya | Awutu Bontrase | 5°35'5.2"N<br>0°33'27.6"W |
| | | Akufful Krodua | 5°42'30.3"N<br>0°31'3"W |
| | | Awutu Ofaso | 5°42'55.7"N<br>0°33'30.7"W |
| | Komenda-Edina-Eguafo-Abirem Municipal | Eguafo | 5°9'40.1"N<br>0°21'42.7"W |
| | | Kissi | 5°5'45.1"N<br>1°31'7.8"W |
| | | Abirem Agona | 5°11'17.8"N<br>1°25'39.8"W |

Source: Field survey, Marfo-Ahenkora (2015)

In total, 12 communities were selected from four districts in two agro-ecological zones (AEZ). The researcher was first introduced to the communities in the study areas. The introduction of the researcher in each community was facilitated by the AEAs of the operational areas. The first meeting gave the researcher the opportunity to introduce herself to the community and to prudently explain the purpose of the research work. The location of the four districts in their regions are shown in Fig 3.1.

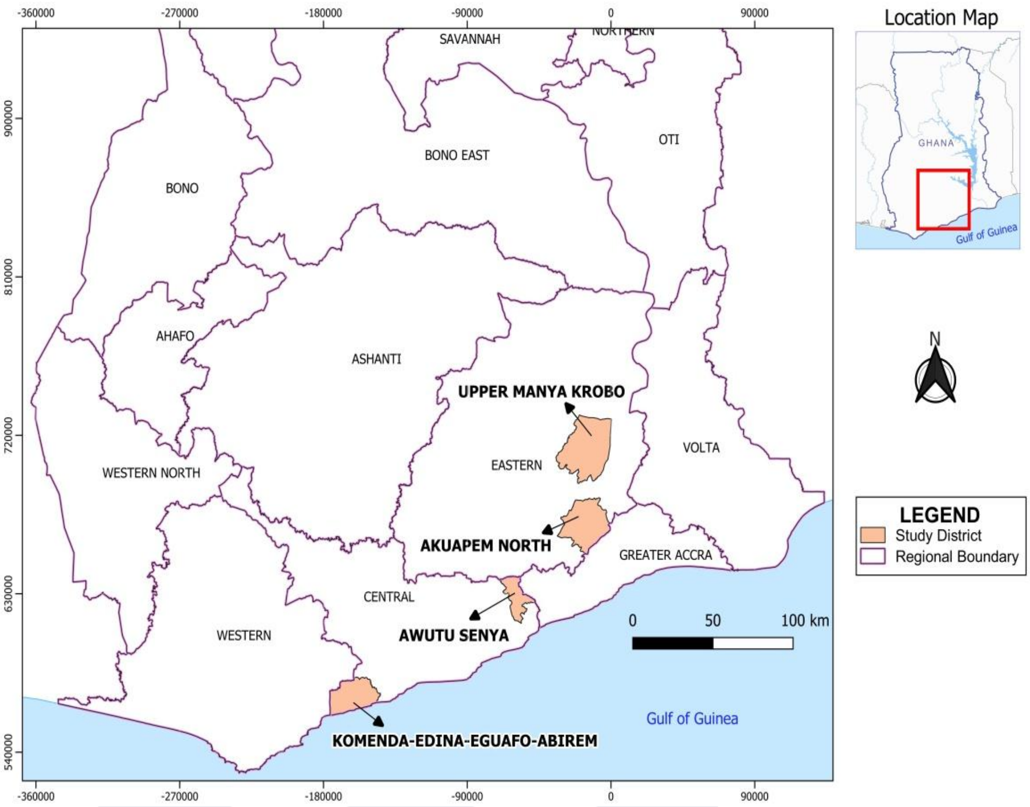


**Figure 3.1: A section of the map of Ghana showing the location of the four districts used for the study.**

**Profiles of selected districts**

All the selected districts have a bimodal rainfall pattern. Generally, the main rains start in April and end in July. There is usually a short dry spell in August and then the minor rains start in September and end in November. The districts experience a long dry spell from December to February and sometimes March.

Table 3.2. is a brief profile of the four districts where the study was conducted.

**Table 3.2: Brief profiles of the districts selected for the study**

| District | Location | Vegetation/ major crops grown | Soil type; FAO classification | Climate |
|---|---|---|---|---|
| Akuapem North | -5$^0$ 51$^0$ 6$^0$ 10$^0$ N<br>-0$^0$ 00$^0$ E and 0$^0$ 20$^0$ E. | -Mainly semi deciduous<br>-Maize, cassava, vegetables, plantain, citrus, oil palm and cocoa. | Mainly Dystric Fluvisols, Cambic Arenosols, Humic Acrisols, Umbric Leptosols | -Mean annual rainfall of 1270 mm<br>-Mean temperature of 21$^0$C -28$^0$C. |
| Upper Manya Krobo | -6.2 - 6.5$^0$N<br>-0.3 - 0.0$^0$ W | -Mainly semi-deciduous forest and derived Savannah zone-<br>-Maize, cassava, rice, vegetables, yam, cocoyam, plantain, sugarcane, oil palm and mango. | Mainly Cambic Arenosols, | -Mean annual rainfall ranging between 900 mm to 1,500 mm -Mean temperature of 23 $^o$C to 32 $^o$C. |
| Awutu Senya | -5$^o$20'N 5$^o$42'N<br>-0$^o$25'W 0$^o$37'W | -Mainly coastal savannah and semi-deciduous forest<br>- Mainly pineapple, maize, cassava, plantain, yam, coconut, pawpaw etc. | Mainly Dystric Leptosols, Haplic Lixisols,<br>-Mainly loamy soils and clayey soils | -Mean annual rainfall ranging between 500 and 700 mm.<br>-The mean temperatures of 22 $^0$C and 28 $^0$C |
| Komenda-Edina-Eguafo-Abirem | -5$^0$ 05' N<br>5$^0$ 15' N<br>-1$^0$ 20' W<br>1$^0$ 40' W. | -Mainly coastal savannah and semi-deciduous -Maize, cassava, plantain sweet potato, coconut, sugarcane etc. | -Mainly Ferric Lixisols, Ferric Acrisols<br>-Mainly sandy clay,gravely and sandy-loam. | -Mean rainfall in coastal areas 750 mm and 1,000 mm.<br>1200 mm 00 for semi deciduous forest areas<br>-Mean temp 21°C to 31°C. |

Source: Field survey, Marfo-Ahenkora (2015)

### 3.3.2. Data collection

Data collection was done in two phases. The Participatory Rural Appraisal (PRA) technique was employed as one of the most appropriate approaches for the identification of community problems and for understanding the socio-economic and cultural aspects of the community. The Participatory Rural Appraisal uses a number of tools for assessing a community's resources, identifying and prioritizing problems and appraising strategies for solving them. Focus group discussions (FGD) using semi-structured interview which is one of the PRA tools was employed for primary data collection. Generally, this diagnostic study involved the use of focus group discussions, key informants interviews and individual interviews using structured questionnaires to explore challenges and opportunities in smallholder maize cultivation in order to enhance productivity of maize in the two agro-ecological zones in Ghana. Transect walk through the communities and farm visits were made to some selected farms as well.

#### 3.3.2.1. Focus group discussions (FGD)

The FGD helps the researcher to have a general overview of the subject matter in a short time. The FGD is a scheduled interview with a small group of people on specific topics (Patton, 2002). The group is composed of people who are specially selected due to their particular interest, expertise or position in the community. They discuss topics in which they are knowledgeable. The method allows the researcher to gain information within a short period of time about the scope or variation of opinions and gives in-depth understanding of issues that are discussed. Semi-structured interview guidelines were developed to guide the collection of data for the FGD. The FGD preceded the formal survey (questionnaire) and helped to develop the structured questionnaire for the second phase. The FGD was conducted between July and August, 2015 in each of the selected study communities with an average of 11 farmers per group. The small number allowed every farmer to have the opportunity to participate in the discussion. The agricultural extension agents (AEAs) in-charge of the operational areas where the communities are situated helped to recruit smallholder maize farmers for the FGD. Membership of each group comprised men and women, opinion leaders and or key informants.

Farmers were engaged in discussions on an array of issues including land tenure, maize variety used, soil management activities, marketing and storage of produce, inputs used, credit facilities and gender roles in maize production in their communities. The FGD was also used to collect data on main production constraints, socio-economic settings, farm organisation, and maize crop management. Voice recordings (with the consent of the farmers) of all proceedings were done during the deliberations in addition to written notes in field note books.

### 3.3.2.2. Survey (Questionnaire)

A survey was conducted to identify farmers' socio-economic / socio-cultural conditions, agronomic practices, resource availability, and climatic factors of production through the administration of a structured questionnaire. Results from the FGD informed the type of questions that were included in the questionnaire.

Enumerators, mostly AEAs were trained for the questionnaire administration. The questionnaire was pretested in both the SDFZ and CSZ in communities not covered in the study but were as similar as possible to those respondents in the study communities based on geographical location, socio-economic and cultural characteristics. The pilot study was conducted with 20 farmers each from Amissano in the KEEA Municipality (CSZ) and Asesewa in the Upper Manya Krobo district (SDFZ) in September 2015. The purpose of the pilot study was to find out whether the questions were clearly understood, easy to answer and time efficient. A final questionnaire was prepared after all concerns that came up during the piloting phase were addressed. The questionnaire used for the study is at Appendix A.

Farmers who planted maize in a monocrop system in addition to their intercrops were purposively selected with the help of the AEAs and then a Random sampling method was exploited in selecting 30 of them within the study areas. Thirty is the minimum sample size for attainment of normal distribution according to the Central Limit Theorem. The questionnaire was administered to each of the 30 farmers selected from each of the 12 communities between September and October 2015. A total number of 360 maize farmers were interviewed of which 215 were males and 145 were females

### 3.3.2.3. Data Analysis

The responses from the FGD were organised under themes. Similar responses were pulled together as well as diverging ones and conclusions drawn. The primary data collected from the 360 respondents was analysed with both descriptive statistics (frequency distributions, percentage response, means and graphs) and inferential statistics such as Chi square test using IBM Statistical Product and Service Solutions (IBM SPSS) version 20.

## 3.4. Results

This section presents the results of the main outcomes of the FGD and the structured questionnaire.

### 3.4.1. Results of Focus Group Discussions (FGD)

The results of the FGD held in the AEZs have been outlined under various sub headings and discussed. Participating farmers in all the communities deliberated their challenges and opportunities dispassionately.

#### 3.4.1.1. Demographic characteristics of the SDFZ and CSZ

Results from the FGD revealed that the communities within the SDFZ and CSZ had relatively higher number of females than males.

Communities in the study areas either had some or all social amenities such as schools, pipe borne water, boreholes, wells, streams, public places of convenience, clinics or health posts and markets as presented in Tables 3.3 & 3.4. There were no market places in the communities in the SDFZ so they all went to neighbouring communities to do their marketing but sometimes market queens bought produce at the farm gate. Mankrado/Otareso and Ahenkorase has a nearby vibrant market centre at Adawso but farmers in Okyerekrom go to Asamanma also a market centre all in the Akuapem North Municipal with designated market days. In the Upper Manya Krobo district, there is a vibrant marketing centre at Asesewa, the district capital with specified market days where farmers from the communities go from time to time. In the study areas of the Awutu Senya district in the CSZ, the farmers in Awutu Ofaso and Akufful Krodua go to Bawdjiase (a big market centre in the district) to access market and other social amenities. Awutu Bontrase however was a market centre with specified market days and so the farmers had a place to sell their produce. At

KEEA, two communities (Kissi and Abirem Agona) had markets but Eguafo did not have a vibrant market and so farmers went to nearby communities to sell their produce.

All the communities in both the SDFZ and the CSZ had been given some form of training in good agricultural practices for various crops from Ministry of Food and Agriculture (MoFA), Millenium Development Authority (MiDA) Adventist Relief Agency (ADRA) and the West Africa Agriculture Productivity Programme (WAAPP) at one time or the other. The farmers present for the FGD indicated that not all of them had the opportunity to participate in such trainings. Some participants indicated that they belonged to farmer associations and have benefitted from such associations by way of hire purchase of farm inputs and access to markets.

Table 3.3: Some characteristics (social amenities, trainings received) of the communities in the SDFZ (FGDs)

| Agro-ecological zone | District | Community | Social/Physical infrastructure | Training received from agencies on good agricultural practices |
|---|---|---|---|---|
| Semi-deciduous forest zone | Akuapem North Municipal | Otareso /Mankrado | Few churches, only kindergarten, boreholes no clinic, , no markets, , no public lavatories, no mosque, | MoFA, MiDA, ADRA |
| | | Okyerekrom | Few churches, boreholes no clinic, no school, no markets, , no public lavatories, no mosque, | MoFA, MiDA, ADRA |
| | | Ahenkorase | Few churches, boreholes no clinic, no school, no markets, no mosque, , no public lavatories | MoFA, MiDA, ADRA |
| | Upper Manya Krobo | Akateng Manya | One church, primary school, boreholes no clinics, no mosques, , , no markets, no public lavatories | MoFA, MiDA, ADRA |
| | | Dzomoa | Few churches, , up to JHS level, boreholes, no clinics, no mosques, , no markets, no public lavatories | MoFA, MiDA, ADRA |
| | | Mensah Dawa | Few churches, mosque, up to JHS level, boreholes , no clinics, , , , no markets, no public lavatories | MoFA, MiDA, ADRA |

Source: Field survey, Marfo-Ahenkora (2015)

Table 3.4: Some characteristics (social amenities, tranings received) of the communities in the CSZ (FGDs)

| Agro-ecological zone | District | Community | Social/physical infrastructure | Training received from agencies on good agricultural practices |
|---|---|---|---|---|
| Coastal savannah zone | Awutu Senya | Awutu Bontrase | Up to SHS, health post, mosques, churches, public lavatory, pipe borne/borehole water, market | MoFA, MiDA, ADRA |
| | | Akufful Krodua | Up to JHS, churches, borehole, no markets, , no clinic, no public lavatories | MoFA, MiDA, ADRA |
| | | Awutu Ofaso | Up to JHS, churches, borehole, no markets, no clinic, no public lavatories, | MoFA, MiDA, ADRA |
| | Komenda-Edina-Eguafo-Abirem | Eguafo | Up to JHS, few churches, public lavatories, no clinic, no markets, no mosque, , | MoFA, MiDA, WAAPP |
| | | Kissi | Up to SHS level, churches, mosques, pipe borne. health posts, markets, public lavatories | MoFA, MiDA, WAAPP |
| | | Abirem Agona | Up to SHS level, churches, mosques, pipe borne. health posts, markets, public lavatories | MoFA, MiDA, WAAPP |

Source: Field survey, Marfo-Ahenkora (2015)

#### 3.4.1.2. Major crops planted and the cropping systems in the SDFZ and CSZ

The farmers in the study areas indicated that, they cultivated other food crops and cash crops in addition to maize (Tables 3.3 & 3.4). The growing of rubber was quite new to the communities but it was fast catching up since the company promoting it gives incentives such as seedlings, fertilizers and sometimes cash to participating farmers. Cropping systems were comparable across the two AEZs and within the communities with mixed cropping dominating. Maize was the first crop cultivated after land preparation and this was followed by cassava as an intercrop. Maize was also sown as a monocrop by farmers who intended to plant both major and minor season maize on the same piece of land. For the tree crops like rubber, citrus, oil palm and coconut, some intercropping was done in the first three to four years with food crops such as plantain, maize and cassava as well as vegetables before the trees began to fruit. Very few farmers practiced crop rotations on their farms. The participants also pointed out that over the years, the planting dates kept shifting and so depending on where their farms were located, they planted between March and May for the major season. They indicated that the dates for the minor season planting varied and that it depended on the rainfall pattern for each year but was generally between September and October.

#### 3.4.1.3. Varieties of maize cultivated, reasons for choice and seed sources.

Farmers present mentioned the maize varieties they were currently using as well as names of previous varieties they knew about (Tables 3.5 & 3.6) and gave reasons why they were not using them again.

Table 3.5: Some characteristics (agricultural production, input used) of the communities in the SDFZ (FGDs)

| Agro-ecological zone | District | Community | Major crops planted | Maize varieties known | Agrochemicals used | Farm animals kept |
|---|---|---|---|---|---|---|
| Semi-deciduous forest zone | Akuapem North Municipal | Otareso/ Mankrado | Maize, cassava, cocoyam, plantain, oil palm, cocoa, citrus and vegetables | Local varieties, Obatanpa , Okomasa and Abelehi | Round up, Gramozone, Atrazine, Nicogan, Nicoking, Nwura Nwura, 2-4- D, Glyfos, NPK | Sheep, goats, pigs, turkey, ducks, chicken and rabbit |
| | | Okyerekrom | Maize, cassava, cocoyam, plantain, oil palm, citrus, cocoa, and vegetables | Local varieties, Obatanpa, Okomasa and Abelehi | Round up, Gramozone, Atrazine, Nicogan, Nicoking, Nwura Nwura,NPK. Ammonia | Sheep, goats, pigs, turkey, ducks, chicken and rabbit |
| | | Ahenkorase | Maize, cassava, cocoyam, plantain, oil palm, cocoa, citrus and pineapple, vegetables | Local varieties, Obatanpa, Pioneer, Okomasa and Abelehi | Round up, Gramozone, Atrazine, Nicogan, Nicoking, Adwuma wura, , 2-4- D, Glyfos, NPK. Ammonia | Sheep, goats, Sigs, turkey, ducks, chicken grasscutter and rabbit |
| | Upper Manya Krobo | Akateng Manya | Maize, cassava, cocoyam, plantain, watermelons, vegetables and rubber | Local varieties, Obatanpa, Okomasa and Abelehi ,Aburotia, Averno, Toxpino | Atrazine, Nicogan, Nicoking, Glyfos Adwumawura, Nwurawura, 2-4- D NPK. Ammonia, | Sheep, goats, pigs, turkey, ducks, chicken and cattle |
| | | Dzomoa | Maize, cassava, cocoyam, plantain, vegetables, watermelons, oil palm, cocoa, citrus and rubber | Local varieties, Obatanpa, Okomasa and Abelehi, Laposta, Global 2000, Dobidi, Aburotia, Toxpino | Atrazine, Nicogan, Nicoking, Glyfos Adwumawura, Nwurawura, 2-4- D, NPK. Ammonia | Sheep, goats, pigs, turkey, ducks and, chicken |
| | | Mensah Dawa | Maize, cassava, cocoyam, plantains, yam,vegetables, watermelon, oil palm, cocoa, citrus and rubber | Local varieties, Obatanpa, Okomasa and Abelehi, Laposta, Global 2000, Toxpino, Dobidi, Aburotia | Atrazine, Nicogan, Nicoking, Glyfos Adwumawura, Nwurawura, 2-4- D, NPK. Ammonia | Sheep, goats, pigs, turkey, ducks, chicken |

Source: Field survey, Marfo-Ahenkora (2015)

Table 3.6: Some characteristics (Agriculture production and inputs used) of the communities in the CSZ (FGDs)

| Agro-ecological zone | District | Community | Major crops planted | Maize varieties known | Agrochemicals used | Livestock kept |
|---|---|---|---|---|---|---|
| Coastal savannah zone | Awutu Senya | Awutu Bontrase | Maize, cassava, plantain, cocoyam, pawpaw, coconut, pineapple, yam, vegetables | Golden crystal, local variety, Mamaba, Obatanpa | Gramozone, Atrazine, Nicogan, Nicoking, Francosate, Adwuma wura, , 2-4- D amine salt and Round - up. NPK. Ammonia | Sheep, goats, pigs, turkey, ducks and chicken. |
| | | Akufful Krodua | Maize, cassava, plantain, cocoyam, pawpaw, coconut, pineapple, yam, vegetables | Dobidi ,Mamaba, Golden crystal, local variety, Obatanpa | Glyphosate, Gramozone, Atrazine, Nicogan, 2-4- D amine salt, Round-up, Nwura Nwura, NPK. Ammonia | Sheep, goats, pigs, turkey, ducks and chicken . |
| | | Awutu Ofaso | Maize, cassava, plantain, cocoyam, pawpaw, coconut, pineapple, yam, vegetables | Dobidi, Mamaba, Golden crystal, local variety, Obatanpa | Gramozone, Atrazine, Nicogan, Nicoking, Francosate, Adwuma wura, NPK. Ammonia | Sheep, goats, pigs, turkey, ducks and chicken. |
| | Komenda-Edina-Eguafo-Abirem | Eguafo | Maize, cassava, plantain, yam, cocoyam, coconut, Sweet potato, pawpaw, water melon, oil palm and citrus | Local, varieties, Golden crystal Obatanpa, Dobidi ,Mamaba | Gramozone, Atrazine, Nicogan, Francosate, Adwuma wura, 2-4- D amine salt, Round- up, NPK. Ammonia | Sheep, goats, pigs, turkey, ducks and chicken. |
| | | Kissi | Sweet potato, cassava, maize, plantain, yam, cocoyam, coconut, pawpaw, watermelon | Local varieties, Golden crystal Obatanpa, Dobidi ,Mamaba | Atrazine, Nicogan, Nicoking, Glyphosate, Adwuma wura, Nwura Nwura and 2-4- D amine, NPK. Ammonia | Sheep, goats, pigs, turkey, ducks and chicken . |
| | | Abirem Agona | Cassava maize, plantain, yam, cocoyam, sweet potato, coconut, pawpaw, oil palm and citrus | Local varieties, Golden crystal Obatanpa, Dobidi ,Mamaba | Atrazine, Nicogan, Nicoking, Glyphosate, Adwuma wura, Nwura Nwura and 2-4- D amine, NPK. Ammonia | Sheep, goats, pigs, turkey, ducks and chicken. |

Source: Field survey, Marfo-Ahenkora (2015)

The common maize varieties used currently in the two agro–ecological zones included Obatanpa (which they called Agric), Golden crystal (common in the CSZ) and some local varieties (white and yellow maize). The common local white maize they used was called ‘Ahomatea’ whilst some farmers in the CSZ also used the name “Owifommpɛ*”* in addition to ‘Ahomatea’. One farmer in Ahenkorase indicated he planted some maize variety provided by pioneer company (yellow maize).

Some farmers said they started growing some of those earlier improved varieties but noticed certain challenges which made them stop cultivating those varieties. They indicated that the Toxpino was short in stature so rodents easily destroy it. They asserted that Global 2000 ‘Dobidi’ and ‘Mamaba’ varieties had bigger and chaffy grains and so buyers especially those who used it for kenkey (steamed fermented corn dough), did not like it any longer. Again they indicated that they no longer planted ‘Abelehi’, ‘Mamaba’ and ‘Okomasa’ because they could not store them for long and weevils destroyed them faster than the local varieties. Almost all the farmers in the study areas planted the local maize (the white, yellow or both). They unanimously agreed that the local maize stored better, and tasted better when used to prepare food compared to Obatanpa and other improved maize varieties (‘agric abro’), even though they conceded that Obatanpa give higher yields. It came up that most farmers planted Obatanpa in order to harvest and sell as fresh cobs because it matured relatively early and had bigger cobs. One farmer from Upper Manya Krobo said “We plant the Obatanpa when we are a bit late in planting because that one matures earlier than the local variety and we are able to sell it fresh because of its bigger cobs". One farmer also said "Obatanpa has more chaff than the local ones and it does not last in storage as compared to the local ones".

Majority of the farmers saved seeds (selected bigger healthy looking cobs) from the previous harvest (farmer saved seed) and some few also occasionally buy seeds from agro-input shops and also from the open market. For all the varieties cultivated including Obatanpa, they used farmer saved seed as planting materials most of the time.

#### 3.4.1.4. Land tenure arrangements

Several types of land tenure arrangements exist in the crop production systems of smallholder farmers in the study areas. These included family/stool lands, farmers own lands, sharecropping, lease or rented lands. Land tenure systems were similar in the AEZs with slight differences in the number of farmers using a particular tenure system. Farmers from the SDFZ indicated that apart from a few people who cropped on family and stool lands, majority of the farmers were engaged in sharecropping and few stated that they rented/leased the land. For those on lease, money is paid and the land is released for the number of years paid for. The land owners preferred shorter lease periods so that they could increase the price for the lease in subsequent years. The farmers stated that the lease amount was usually between GH¢ 400.00 and GH¢ 500.00 per hectare per annum in the SDFZ depending on the proximity of farm land to the community. In the CSZ however, the majority of farmers rented/leased the land and some others did sharecropping. The price for the lease (known as '*Akoffie*' in some coastal communities) ranged between GH¢ 500.00 and GH¢ 750.00 per hectare per annum. Generally, the amount charged for lease/land rentals was higher (GH¢ 500.00 to GH¢ 750.00) in the CSZ compared to the SDFZ (GH¢ 400.00 to GH¢ 500.00).

Leasing was more common than sharecropping in the Awutu Senya district of the CSZ. The farmers in this district pointed out that most of the lands had been given to large scale commercial farmers who in turn sublet to smallholders after using the land basically for pineapple production.

For the sharecroppers, the land for maize cultivation was usually given out in 'Abusa' and or 'Abunu'. According to them, in the case where the farmer buys the inputs it is shared in 'Abusa'. In the 'Abusa' system, the farm produce is divided into three equal parts; the farmer takes two parts and the one part is for the landowner. If the landowner buys the inputs it is shared in 'Abunu'. In the 'Abunu' system, the farm produce is shared into two equal parts; the farmer takes one and the landowner takes the other. The farmers said the 'Abunu' system is becoming common now even though the landowners do not provide any inputs as it used to pertain some time ago. Sometimes in the 'Abunu' or 'Abusa' system, the farmer pays a little token with a drink (schnapps) in the presence of witnesses for two main reasons. First, it is to confirm the conditions agreed to the release of the land in the presence of witnesses and also to mean that the land is the bonafide property of the landowner and not the tenant (done to forestall any litigation with the owner). The conditions for the 'Abunu' and 'Abusa' were similar in both the SDFZ and CSZ. Across the zones, the farmers generally agreed that the lease was more profitable to the farmer and the sharecropping was more profitable to the landowner so most of the landowners were resorting to sharecropping than lease especially in the SDFZ. A farmer remarked that, "The lease is more profitable because we have all the produce to ourselves". Accessing land for farming was generally a challenge for the communities in the CSZ more than the SDFZ.

Most of the participants at the FGD indicated that the land tenure terms had not affected their soil fertility management activities.

### 3.4.1.5. Soil fertility management

The use of fertilizer was very low among participants. Very few farmers stated that they currently apply fertilizer on their maize farms. Some participants said the fertilizer they used was given by a rubber company but since the young rubber trees were on the same plots with the maize, the two crops all benefited from the fertilizer. Most of the farmers agreed that they have not applied fertilizer to their fields for the past 2-5 years even though they knew very well that fertilizer could improve their yields. They gave varying rates of application of the fertilizer on their maize fields. The farmers indicated that compound fertilizers like N P K 15-15-15 were used because it is much more easily available than straight fertilizers such as, urea, single super phosphate or muriate of potash even though they said ammonium sulphate fertilizer was also available sometimes. Across the AEZs, the participants who indicated that they used fertilizer alluded that when fertilizer was applied in the major season, they did not apply again in the minor season because they believed that the major season fertilizer will be in the soil (residual effect) to cater for the maize grown in the minor season. Some farmers were of the view that although fertilizer application could increase their yields, it affected the quality in terms of taste and storability of the maize. The farmers attributed their lack or low use of fertilizer to among other things, high cost of fertilizer, transportation cost, lack of labour and perception of poor organoleptic properties associated with fertilizer application. The farmers appreciated the government policy on fertilizer subsidy but had reservations with its implementation. They said sometimes the transport cost to pick the subsidised fertilizer erases the benefit of the subsidy and argued that the fertilizer should be brought to the communities for easy access and not the district offices as is currently being done.

The farmers disclosed that they did not use manure as soil amendment for their maize farms. Some farmers in the communities indicated that they had attended farmer field schools where they were taught how to compost manure but they did not practice it. Generally, the farmers were not too sure of the benefits of using animal manure to amend the soil in their maize production systems. Even though they seem to know the importance of crop rotation, it was not widely practiced among farmers basically due to land tenure terms. Most of the communities did not plant legumes (which could be used in rotations) and those who did, planted on a small portion of their land just for domestic use. Soil nutrient improvement practices was therefore lacking in most of the communities.

#### 3.4.1.6. Land preparation and weed control

The land preparation methods were similar across the two agro ecological zones. The most prevalent land preparation method was slash (clearing of weeds) and burn (burning of weeds). After the slash and burn, some farmers allow the weeds to regrow and then apply herbicide before sowing. Others also simply did slash and burn without any application of herbicide before sowing. Some farmers who preferred the slash, burn and herbicide application method to the usual slash and burn method said this method reduces the weeding times to just once or twice before harvest. Some farmers (especially in the coastal communities) also plough the land. The farmers in those communities indicated that tractor services were scarce in the communities especially Akufful Krodua in the CSZ and so in as much as they would have liked to plough their fields, the tractors were not available at the time they were needed. The farmers mentioned some of the weedicides used in their communities (Tables 3.5 &3.6). All participants from the various communities revealed that herbicides currently play a major role in their land preparation and subsequent weed control. The challenge had been the proliferation of inferior or substandard products on the market and the use of the correct dosage to avoid long term negative effects on the soils and on human health. They alluded that it has become very difficult to get manual labour for farm operations hence their reliance on herbicides. They stated that, the herbicides come in all forms and shades and that it was sometimes supplied by itinerant traders or bought from agro input shops in nearby communities or in the markets on market days. Most farmers did not wear the required protective clothing during herbicide application even though some of them seem to know that this could have adverse effect on their health. Furthermore, improper disposal of chemical containers as was mentioned is likely to have negative impact on the environment.

Some participants said they planted in rows and others said they did not engage in it because they did not have enough labour and could not do it alone. Row planting was seen as drudgery for some of the participants who confirmed they did not engage in it. Some farmers who did not plant in rows gave the reasons for their decisions. A farmer said "if we plant in rows with the correct planting distance and do not apply fertilizer, we record low yields because our soils are poor in nutrients so we plant randomly with large spaces in between plants and the yield is better". Most farmers present agreed to this notion. Wide planting distances was seen as a means of combating declining soil fertility in the communities.

### 3.4.1.7. Importance of maize to the farm family

Across the agro ecological zones, most of the farmers alluded to the fact that maize was their first staple crop and was used to prepare different dishes. Maize was also sold to generate income (fresh cobs and dried grains) and utilized as feed for poultry, pigs and rarely for small ruminants. At Akateng Manya in the SDFZ, some farmers said they fed the fresh leaves and also the fresh husks from the maize cobs to ruminants. Some farmers in the CSZ disclosed that the maize stalk when dried was used as fuel to smoke fish. Maize was also used in the local brewing industry (both alcoholic and non-alcoholic beverages) and most of the farmers also said they stored it for food security.

### 3.4.1.8. Overall challenges faced by maize farmers in the study areas

The farmers gave a summary of some of the challenges they faced in their maize production enterprise. They complained about lack of funds and not getting access to credit in the form of loans or inputs and the fact that this has limited their ability to crop on a large scale or increase productivity. Lack of financial support for farming was one of the major challenges faced by farmers in the study areas.

The problem of pricing of maize was also a major issue in the study areas. The farmers complained about not having a standard unit of measure and price for maize and hence the aggregators who came to buy their produce came with their own measuring containers and dictated the prices to them. Lack of reliable markets was found to be one of the main constraints faced by these smallholder farmers. Many of the participants said they received low prices for their produce by selling them immediately after harvest at the farm gate or local markets mostly due to lack of storage facilities and also economic hardships. A farmer said “We are not happy with the market price at all because the traders dictate the price and sometimes you have no option than to sell it to them because you need the money”. They wanted the government to establish a standard price just as has been done for cocoa and also for government to buy the produce off after they had harvested and dried them so that they would be assured of stable and uniform prices for their produce. Unstable maize prices were also part of the reasons why they did not want to invest in agro-inputs.

From the discussions it came to light that the unpredictable weather conditions was also one of the major reasons why investing in inputs such as fertilizer and certified seed maize was a bother to the farmers. The farmers indicated that the costs of inputs were too high so when they were able to purchase some inputs and the rains failed or prices fell for that season, then it means they have lost totally. They unanimously agreed that they were observing great changes in the weather pattern and sometimes had to replant 2-3 times on the same piece of land in a season. This was because sometimes when they sow, the rains stopped abruptly and the seedlings withered and so they had to replant when the rains eventually come again. So if they were using seeds from the agro-input shops, they would have to buy seeds each time it failed and that would be a drain on their small budgets. They argued that once there was enough rainfall, the maize will grow well even if the soil fertility is low. Risk of crop failure was therefore a major reason why farmers did not want to invest in agro-inputs such as fertilizer, pesticide and seed maize but were satisfied with herbicides for weed control.

Storage of maize after harvesting was mentioned as a major challenge in these communities. There were complaints of farmers not having enough drying and storage facilities. They revealed that they have challenges with drying of maize especially with the major season harvest. This was because oftentimes, the major season harvest coincided with the minor season rains making it difficult for them to dry the maize effectively after harvest.

### 3.4.1.9.Gender roles in maize production

There seemed to be a division of labour between the genders. With the men mostly involved in land preparation, weed control, herbicide application, and planting. The women and youth were also part of the planting, post planting weed control, harvesting, shelling and also actively involved in the marketing of farm produce. Women's labour contribution in maize production was quite significant in the study areas.

### 3.4.1.10. Livestock Production

Most farmers present at the FGD in all the study areas, kept one form of livestock or the other (Tables 3.4 & 3.6). Small ruminants were the most popular among the livestock mentioned. Some of the farmers saw the keeping of livestock as a form of security which they could rely on in the event of crop failure. In all the communities in the study areas, there were no communal grazing lands for ruminant livestock feeding. Some of the main challenges of small ruminants rearing in the communities were the high level of theft and the occasional diseases that plagued the livestock. A farmer from Ahenkorase in the SDFZ said "They steal the small ruminants too often so I have stopped rearing them". The farmers in the study areas said they do not utilize the manure from their livestock for maize production. They rather sweep it away together with other debris except at Akufful Krodua where one farmer said he was using goat manure for his maize farm.

### 3.4.2. Results of survey (Questionnaire)

#### 3.4.2.1. Questionnaire Return Rate

The study sample was 360 randomly selected maize farmers from the two AEZs made up of 180 farmers from the CSZ and 180 from the SDFZ. The return rate was 100% because the questionnaires were administered with the support of Agricultural Extension Agents (AEAs) from the districts where the research was carried out.

#### 3.4.2.2. Socio-demographic characteristics of maize farmers interviewed.

This section describes the personal information of respondents such as gender, age, educational level, years of experience in maize farming, farming as main occupation, total acreage of the maize farms and their membership of farmer associations.

### *Gender distribution of respondents*

Figure 3.2 shows the gender distribution of respondents in the two AEZs. The CSZ had 55.6% males and 44.4% females while the SDFZ had 63.9% males and 36.1% females.

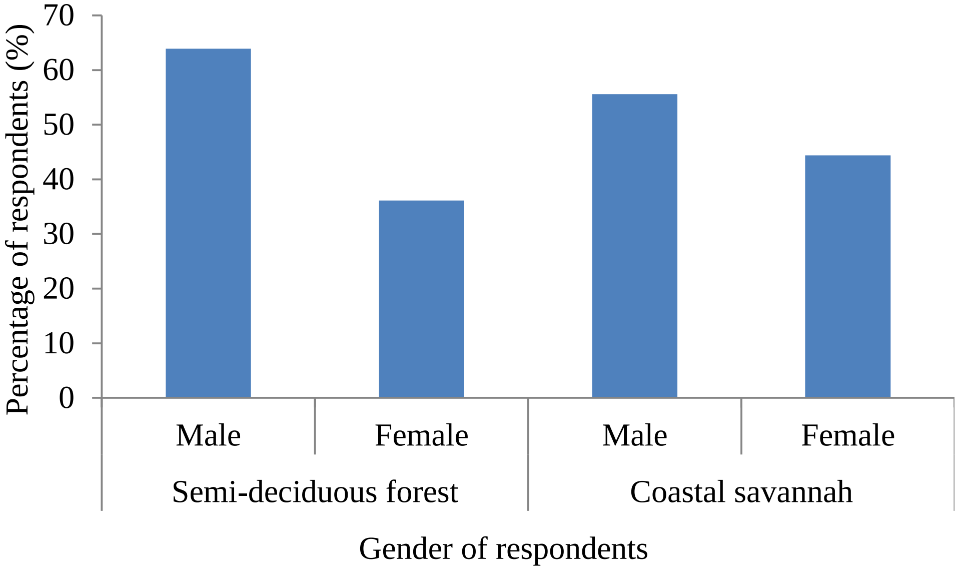


**Figure 3.2: Gender distribution of respondents**

Source: Field survey, Marfo-Ahenkora (2015)

### *Age distribution of respondents*

The age distributions of the respondents are shown in Figure 3.3. The majority of the respondents in both SDFZ (72.2%) and CSZ (67.7%) were in the age range of 41 and above 60 years. About 27.8% and 32.3% of the farmers in the SDFZ and CSZ respectively were in the age range of 21-40 years.

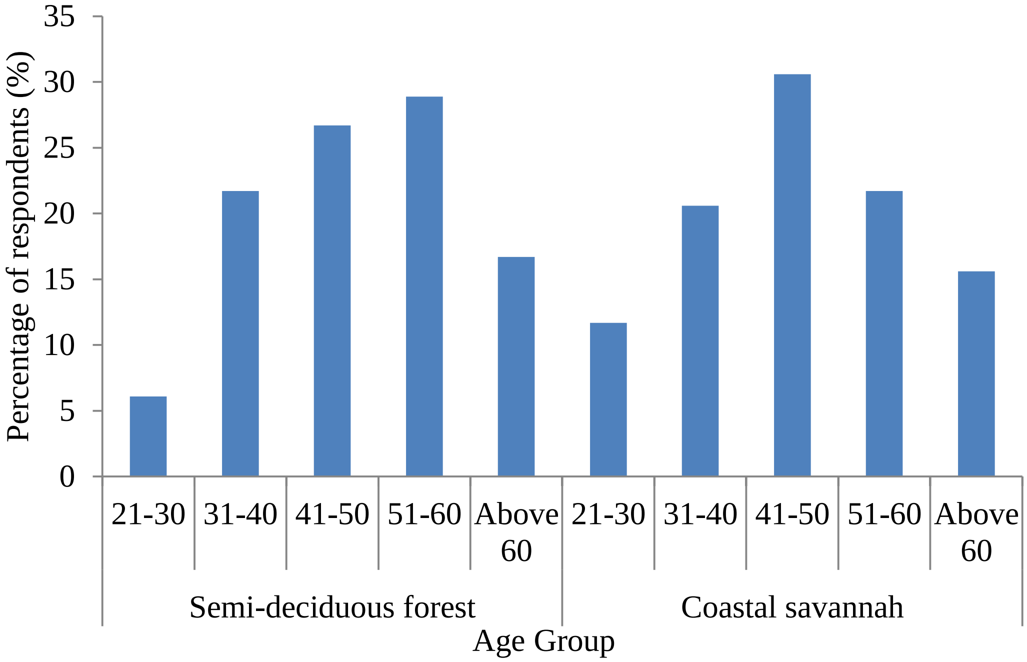


**Figure 3.3: Age distribution of respondents**

Source: Field survey, Marfo-Ahenkora (2015)

***Level of education***

The levels of education of respondents are presented in Table 3.7. Majority of respondents had basic education recording 65.6% and 71.1% in the SDFZ and CSZ respectively.

**Table 3.7: Level of education of respondents**

| Agro-ecological zone | Level of education | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Basic | 118 | 65.6 |
| | Sec/Tech/Vocational | 16 | 8.9 |
| | Non formal education | 46 | 25.6 |
| Coastal savannah | Basic | 128 | 71.1 |
| | Sec/Tech/Vocational | 19 | 10.6 |
| | Non formal education | 33 | 18.3 |

Source: Field survey, Marfo-Ahenkora (2015)

Farmers in the SDFZ (25.6%) and 18.3% of farmers in the CSZ had not been to school before. Only 8.8% and 10.6% in the SDFZ and the CSZ respectively had education up to secondary level (Table 3.7).

***Years of experience in maize farming***

Years of experience in maize farming of respondents is shown in Table 3.8.

**Table 3.8: Years of experience in maize farming**

| Agro-ecological zone | No. of years in maize farming | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | 1 - 5 | 14 | 7.8 |
| | 6- 10 | 29 | 16.1 |
| | 11 -15 | 4 | 2.2 |
| | above 15 | 133 | 73.9 |
| Coastal savannah | 1 - 5 | 20 | 11.1 |
| | 6 - 10 | 31 | 17.2 |
| | 11 - 15 | 12 | 6.7 |
| | above 15 | 117 | 65.0 |

Source: Field survey, Marfo-Ahenkora (2015)

Majority of the farmers had been farming for more than 15 years in both SDFZ (73.9%) and CSZ (65%). About 16.1% of them in the SDFZ and 17.2% in the CSZ had been farming for between 6 to 10 years (Table 3.8). Relatively few farmers (11.1%) in the CSZ and (7.8%) in the SDFZ had been farming between one to five years.

***Farming as main occupation.***

In the CSZ, 81% of respondents had farming as their main occupation while 87% of respondents in the SDFZ had farming as main occupation (Figure 3.4).

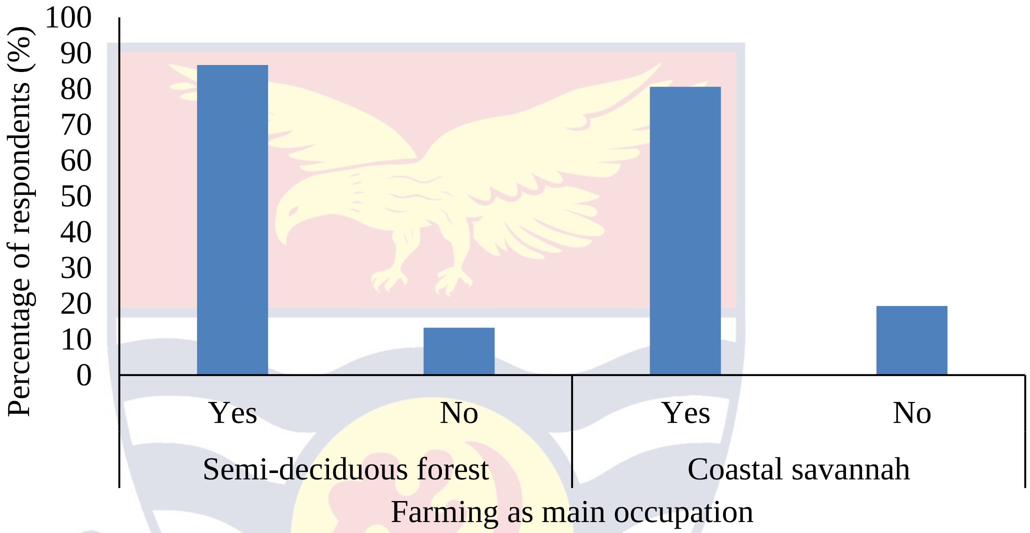


**Figure 3.4 Farming as main occupation**

Source: Field surve, Marfo-Ahenkora (2015)

***Total Acreage for maize cultivation***

In the SDFZ, the highest number of respondents (38.3%) had land holdings of 0.82 – 1.62 hectares for maize. This was followed by 33.3% of the respondents who had land holdings of 0.20 – 0.81 hectares in the same AEZ (Figure 3.5).

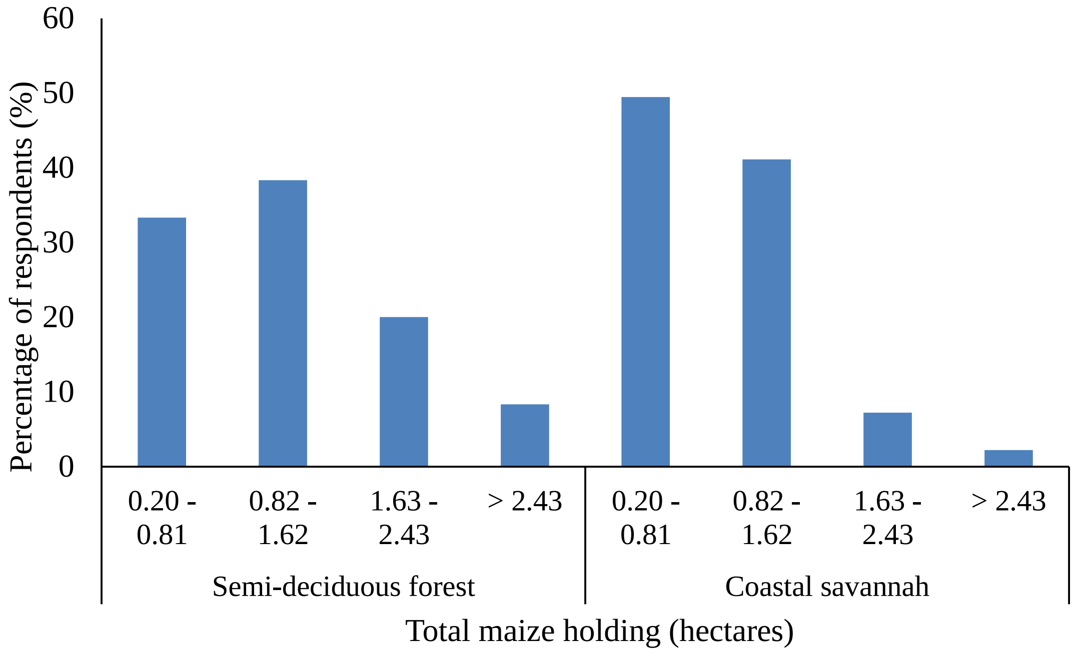


**Figure 3.5: Distribution of respondents based on maize farm size**

Source: Field survey, Marfo-Ahenkora (2015)

In the CSZ however, majority of respondents (49.4%), had land holdings between 0.20 to 0.81 hectares followed by 41.1% respondents who had land holdings of 0.82 – 1.62 hectares. Only 8.3% and 2.2% respondents had maize farms above 2.43 hectares in the SDFZ and the CSZ respectively (Figure 3.5).

***Farmer association***

Majority of respondents (58.3%) in the SDFZ indicated that they belonged to farmer associations. The CSZ on the other hand, had majority of respondents (53.9%) not belonging to any farmer association (Figure 3.6).

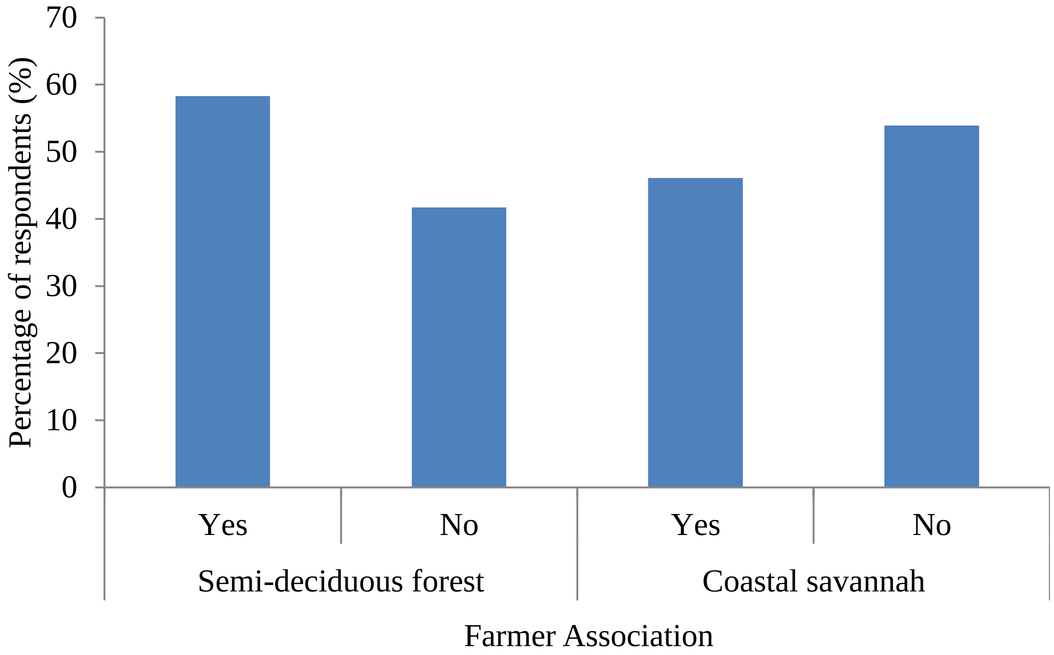


**Figure 3.6: Membership of farmer association**

Source: Field survey, Marfo-Ahenkora (2015)

***Land tenure arrangements***

The majority of respondents in the SDFZ are sharecroppers (43.3%); 11.7% have leasehold or rent the lands with 22.2% and 22.8% farming on family lands and on their own lands respectively (Table 3.9). In the CSZ, the majority lease or rent the land (39.4%), followed by those who farm on family lands (31.7%) with 20% and 8.9% as sharecroppers and land owners respectively. A lot more farmers (22.8%) in the SDFZ, farm on their own lands compared to the CSZ where only 8.9% of farmers possess their own land. On the other hand, about one-third of the respondents (31.7%) in the CSZ depended on family lands for maize cultivation compared to those in the SDFZ where about one-fifth (22.2%) of respondents depended on family lands.

**Table 3.9: Land tenure systems of respondents.**

| Agro-ecological zone | Land tenure system | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Family | 40 | 22.2 |
| | Sharecropping | 78 | 43.3 |
| | Lease | 21 | 11.7 |
| | Own land | 41 | 22.8 |
| Coastal savannah | Family | 57 | 31.7 |
| | Sharecropping | 36 | 20.0 |
| | Lease | 71 | 39.4 |
| | Own land | 16 | 8.9 |

Source: Field survey, Marfo-Ahenkora (2015)

#### 3.4.2.3. Maize production practices

***Maize varieties cultivated in the study areas.***

Maize varieties cultivated by respondents have been presented in Table 3.10. Respondents who planted Obatanpa alone were 21.1% in the SDFZ and 19.4% in the CSZ. Respondents who planted the local white maize (mainly 'Ahomatea' and 'Owifonpe') had the highest percentage (54.4%) in the SDFZ. The percentage of respondent in CSZ growing only local white maize were about half (26.1%) that of the SDFZ. Obatanpa and the local white varieties were the predominant maize varieties grown either alone or in combination with other varieties in both AEZs. Obatanpa was the most popular improved maize variety planted in both AEZ (Table 3.10).

**Table 3.10: Maize varieties cultivated by the respondents in both SDFZ and CSZ**

| Agro-ecological zone | Maize variety | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Obatanpa | 38 | 21.1 |
| | Local white | 98 | 54.4 |
| | Local white &Obatanpa | 18 | 10 |
| | Local yellow & Obatanpa | 2 | 1.1 |
| | Golden Crystal & Obatanpa | 2 | 1.1 |
| | Local (white & yellow) | 19 | 10.6 |
| | Obatanpa, Local white & Golden Crystal | 3 | 1.7 |
| Coastal savannah | Obatanpa | 35 | 19.4 |
| | Local white | 47 | 26.1 |
| | Local white &Obatanpa | 59 | 32.8 |
| | Local yellow & Obatanpa | 5 | 2.8 |
| | Golden Crystal & Obatanpa | 19 | 10.6 |
| | Local (white & yellow) | 1 | 0.6 |
| | Obatanpa, Local white & Golden Crystal | 14 | 7.8 |

Source: Field survey, Marfo-Ahenkora (2015)

### *Sources of seed maize*

The sources of seed maize of respondents have been summarised in Table 3.11. Most respondents in the SDFZ (101) and the CSZ (81) said they used seeds from their own farm (farmer saved seeds-FFS) for the next seasons planting (Table 3.11). Some respondents also indicated that they obtained some seeds from family and friends in addition to what they saved from their own farm so essentially they also used farmer saved seeds. The farmer saved seeds included seeds from both the local varieties and improved varieties. It was however observed that some farmers (19.5%) from the SDFZ and 26.7% from the CSZ still purchased seeds from seed growers and agro-input shops for planting.

**Table 3.11: Sources of seed maize of respondents in the SDFZ and CSZ**

| Agro-ecological zone | Seed source | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Own farm (FSS) | 101 | 56.1 |
| | Own farm, family & friends | 24 | 13.3 |
| | Certified Seed Growers/ Agro-input shops | 35 | 19.5 |
| | Own farm, Certified Seed Growers/ Agro shops | 20 | 11.1 |
| Coastal savannah | Own farm (FSS) | 81 | 45.0 |
| | Own farm, family & friends | 12 | 6.7 |
| | Certified Seed Growers/ Agro Input shops | 48 | 26.7 |
| | Own farm, Certified Seed Growers/ Agro shops | 39 | 21.6 |

Source: Field survey, Marfo-Ahenkora (2015)

***Methods of land preparation***

Land preparation methods used by respondents have been summarised in Table 3.12. Slash, burn and herbicide application was the most preferred land preparation method in the two agro eco zones with 75% using this method in the SDFZ and 68.9% in the CSZ. The other group of farmers who do only slash and burn without applying herbicide were the next to follow with 13.3% in the SDFZ and 24.4% in the CSZ. So essentially, slash and burn and slash/burn and herbicide application dominated the land preparation method across the zones with about 88.3% and 93.3% of the respondents in the SDFZ and the CSZ respectively using these methods (Table 3.12). Only few farmers (6.1%) ploughed with tractor in both AEZs.

**Table 3.12: Land preparation methods of respondents in the SDFZ and CSZ**

| Agro-ecological zone | Land preparation method | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | slash and burn | 24 | 13.3 |
| | Plough with tractor | 8 | 4.4 |
| | zero tillage | 3 | 1.7 |
| | cutlass/hoe-no burning | 10 | 5.6 |
| | slash/burn herbicide | 135 | 75 |
| Coastal savannah | slash and burn | 44 | 24.4 |
| | Plough with tractor | 3 | 1.7 |
| | zero tillage | 7 | 3.9 |
| | cutlass/hoe-no burning | 2 | 1.1 |
| | slash / burn herbicide | 124 | 68.9 |

Source: Field survey, Marfo-Ahenkora (2015)

### *Weed control in maize farms*

Weed control methods used by respondents have been summarised in Table 3.13. Majority of respondents used herbicide for weed control in both agro ecological zones. In the SDFZ, 54.4% of respondents used herbicide alone as their weed control method. This was followed by herbicide and cutlass (20%) and cutlass alone (11.1%). In the CSZ, respondents who used herbicide and hoe (30.6%) followed the herbicide alone (35.6%) which was the highest percentage for the CSZ (Table 3.13). Herbicide use was more prevalent in the SDFZ.

**Table 3.13: Methods of weed control**

| Agro- ecological zone | Weed control method | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Herbicide | 98 | 54.4 |
| | Hoe | 7 | 3.9 |
| | Cutlass | 20 | 11.1 |
| | Herbicide, Hoe | 7 | 3.9 |
| | Herbicide, Cutlass | 36 | 20 |
| | Hoe, Cutlass | 7 | 3.9 |
| | Herbicide, Hoe and Cutlass | 5 | 2.8 |
| Coastal savannah | Herbicide | 64 | 35.6 |
| | Hoe | 13 | 7.2 |
| | Cutlass | 16 | 8.9 |
| | Herbicide, Hoe | 55 | 30.6 |
| | Herbicide, Cutlass | 21 | 11.7 |
| | Hoe, Cutlass | 6 | 3.3 |
| | Herbicide, Hoe and Cutlass | 5 | 2.8 |

Source: Field survey, Marfo-Ahenkora (2015)

### *Sowing pattern*

The sowing patterns (row) of respondents for maize cultivation have been presented in Figure 3.7. The number of respondents planting in rows were quite high (75.6% in the SDFZ and 76.1% in CSZ). A transect walk through some of the farms surveyed in the study areas, revealed that farmers who did row planting were using relatively wider spacing than the recommended one giving reasons such as low soil fertility for their practice.

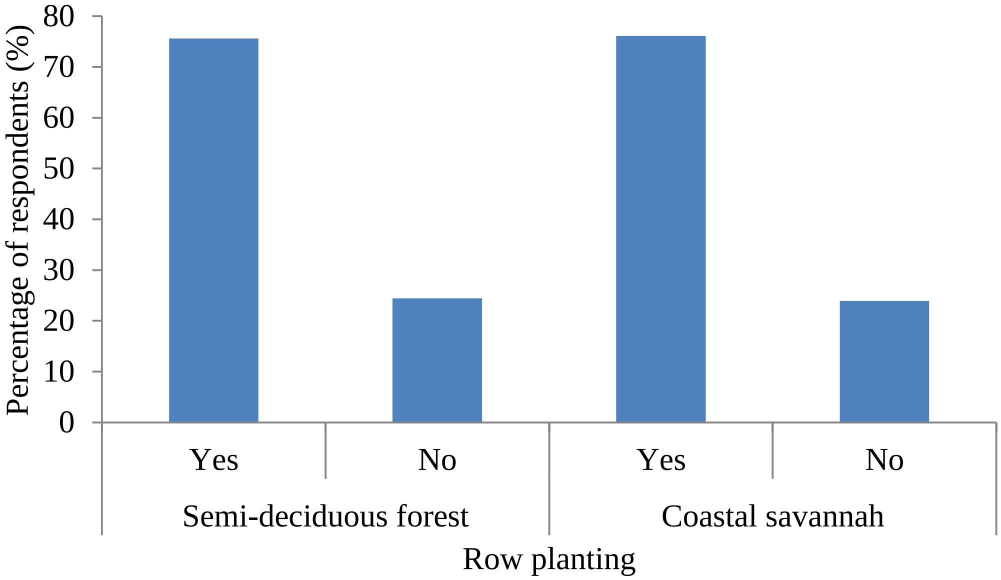


**Figure 3.7: Number of respondents planting in rows**

Source: Field survey, Marfo-Ahenkora (2015)

***Grain yield estimates***

Majority of farmers (25.6%) in the SDFZ gave their yields as 720 kg ha$^{-1}$ (Table 3.14). In the CSZ on the other hand, majority of respondents (27.2%) had yields of 600 kg ha$^{-1}$. The highest yield recorded in the SDFZ was 1,440 kg ha$^{-1}$ recorded by 6.1% of the respondents whereas the highest yield of 1,500 kg ha$^{-1}$ in the CSZ was recorded by only 0.6% of the respondents (Table 3.14).

Table 3.14: Estimates of grain yield (kg ha$^{-1}$) realised by the respondents

| Agro-ecological zone | Yield (kg ha $^{-1}$) | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | 360 | 3 | 1.7 |
| | 480 | 36 | 20 |
| | 600 | 38 | 21.1 |
| | 720 | 46 | 25.6 |
| | 840 | 6 | 3.3 |
| | 900 | 1 | 0.6 |
| | 960 | 17 | 9.4 |
| | 1080 | 3 | 1.7 |
| | 1200 | 19 | 10.6 |
| | 1440 | 11 | 6.1 |
| Coastal savannah | 360 | 2 | 1.1 |
| | 480 | 43 | 23.9 |
| | 600 | 49 | 27.2 |
| | 720 | 35 | 19.4 |
| | 840 | 1 | 0.6 |
| | 900 | 7 | 3.9 |
| | 960 | 13 | 7.2 |
| | 1080 | 2 | 1.1 |
| | 1200 | 20 | 11.1 |
| | 1440 | 7 | 3.9 |
| | 1500 | 1 | 0.6 |

Source: Field survey, Marfo-Ahenkora (2015)

### *Farmers' perception of causes of low yields*

**Table 3.15: Perceived causes of low maize yields**

| Agro-ecological zone | Causes of low maize yields | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Unfavourable weather conditions | 73 | 60.8 |
| | Poor/ infertile soil | 10 | 8.4 |
| N=120 | Lack of inputs (credit, fertilizer, weedicides) | 30 | 25.0 |
| | Poor maintenance and general crop husbandry | 6 | 5.0 |
| | Insect pests and diseases | 1 | 0.8 |
| Coastal savannah | Unfavourable weather conditions | 73 | 77.7 |
| N=94 | Poor/ infertile soil | 11 | 11.7 |
| | Lack of inputs (credit, fertilizer, weedicides) | 8 | 8.5 |
| | Poor maintenance and general crop husbandry | 2 | 2.1 |

Source: Field survey, Marfo-Ahenkora (2015)

Farmers gave various reasons why they have not been able to achieve yield targets (Table 3.15). Unfavourable weather conditions had the highest percentages of 60.8% and 77.7% in the SDFZ and the CSZ respectively. Lack of farm inputs had the second highest percentage (25%) in the SDFZ whilst poor/non fertile soil had 11.7% in the CSZ. Insect pests and diseases had the least (0.8%) in the SDFZ whilst poor maintenance and general crop husbandry recorded the least in the CSZ (2.1%). Farmers in the study areas chose unfavourable weather conditions as the most important cause of low yields across the zones.

### 3.4.2.4. Management of soil fertility

***Application of fertilizer in the last 5 years***

Application of fertilizer in the last 5 years by respondents is presented in Figure 3.8. The majority of respondents 52.8% and 55.0% from SDFZ and CSZ respectively stated that, they had not used fertilizer at all in the last five years whereas 47.2% of respondents in the SDFZ and 45.0% in the CSZ also indicated that they had used fertilizer in the last five years (Figure 3.8).

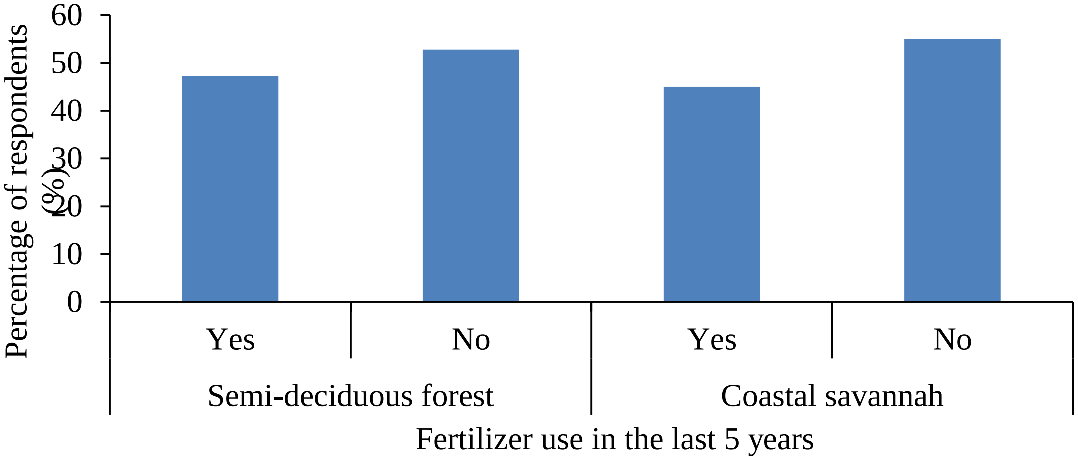
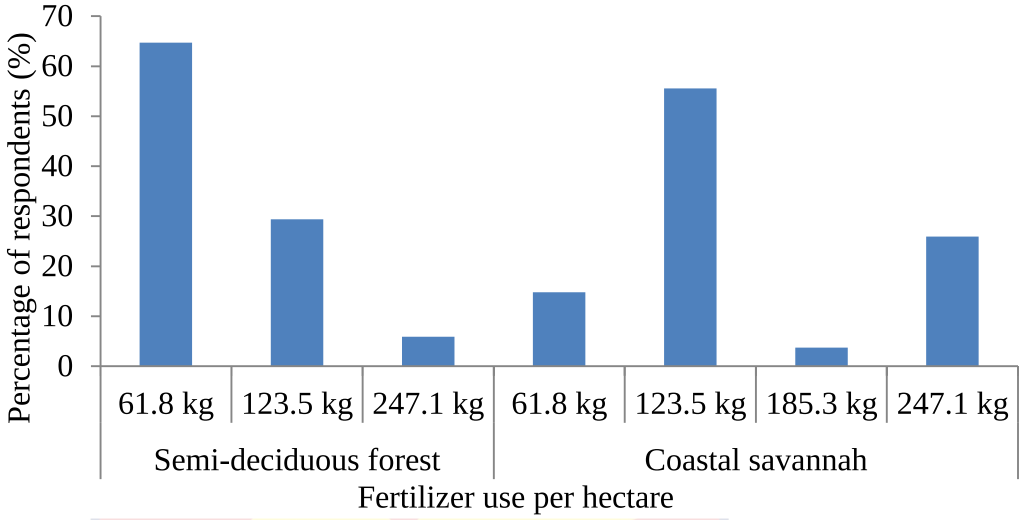


**Figure 3.8: Fertilizer use among farmers in the two AEZs in the last 5 years**

Source: Field survey, Marfo-Ahenkora (2015)

***Fertilizer use per hectare***

Respondents who applied fertilizer in the communities were asked to indicate the quantity applied per hectare. The results are presented in Figure 3.9. In the SDFZ majority of the respondents (64.7%) applied 61.8 kg ha$^{-1}$ (half bag/acre) of fertilizer whereas in the CSZ, the majority of the respondents (55.6%) applied 123.5 kg ha$^{-1}$ (one bag /acre) of fertilizer. In the SDFZ, few farmers (5.9%) applied 247.1 kg ha$^{-1}$ (two bags /acre) whereas in the CSZ, 25.9% applied 247.1 kg ha$^{-1}$ (two bags /acre) of inorganic fertilizer (Figure 3.9).



N (SDFZ) = 85

N (CSZ) = 81

**Figure 3.9: Fertilizer usage per hectare among farmers**

Source: Field survey, Marfo-Ahenkora (2015)

***Reasons for not applying fertilizer***

Majority of farmers interviewed from SDFZ (55.8% and CSZ (44.4%) gave high cost as the reason for not applying fertilizer (Table 3.16). Fertile land was the second highest reason why they did not apply fertilizer (SDFZ (36.8% and CSZ (40.4%).

**Table 3.26: Reasons for not applying fertilizer**

| Agro-ecological zone | Reasons for no fertilizer use | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Fertile land | 35 | 36.8 |
| SDFZ (N) = 95 | High cost | 53 | 55.8 |
| | Bad food taste | 4 | 4.3 |
| | Cannot apply | 2 | 2.1 |
| | I do not like it | 1 | 1.1 |
| Coastal savannah | Fertile land | 40 | 40.4 |
| CSZ (N) = 99 | High cost | 44 | 44.4 |
| | Bad food taste | 5 | 5 |
| | Cannot apply | 8 | 8.1 |
| | I do not like it | 2 | 2 |

Source: Field survey, Marfo-Ahenkora (2015)

### *Manure use for crop farming*

Majority of farmers in the SDFZ (93.9%) and in the CSZ (95.6%) had never used manure for crop farming (Figure 3.10).

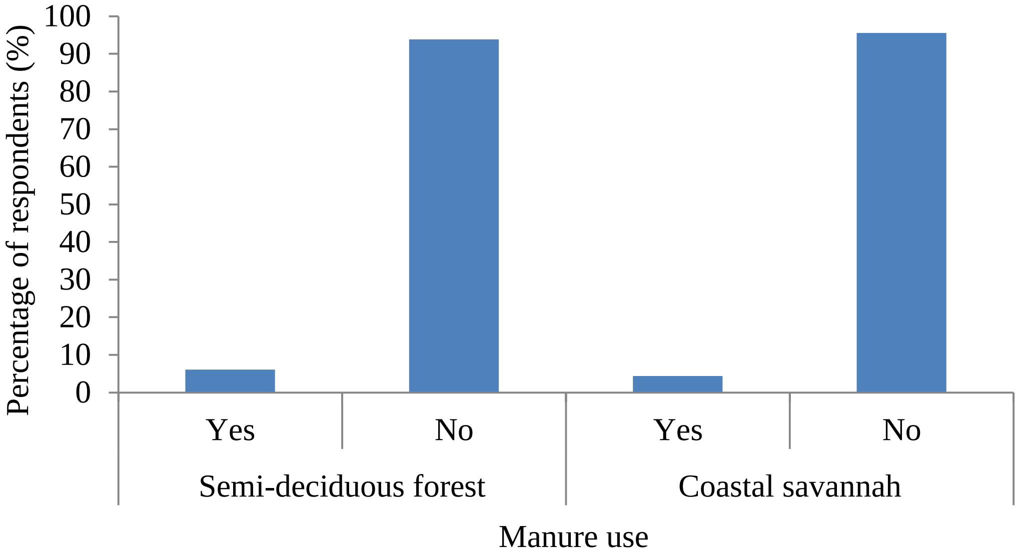


**Figure 3.10: Use of animal manure among farmers**

Source: Field survey, Marfo-Ahenkora (2015)

### *Crop rotation on maize farm*

Majority of maize farmers interviewed in both SDFZ (82%) and CSZ (83%) did not practice crop rotation on their maize farms. Only 18% of respondents from SDFZ and 16% from CSZ indicated that they practiced crop rotation (Figure 3.11).

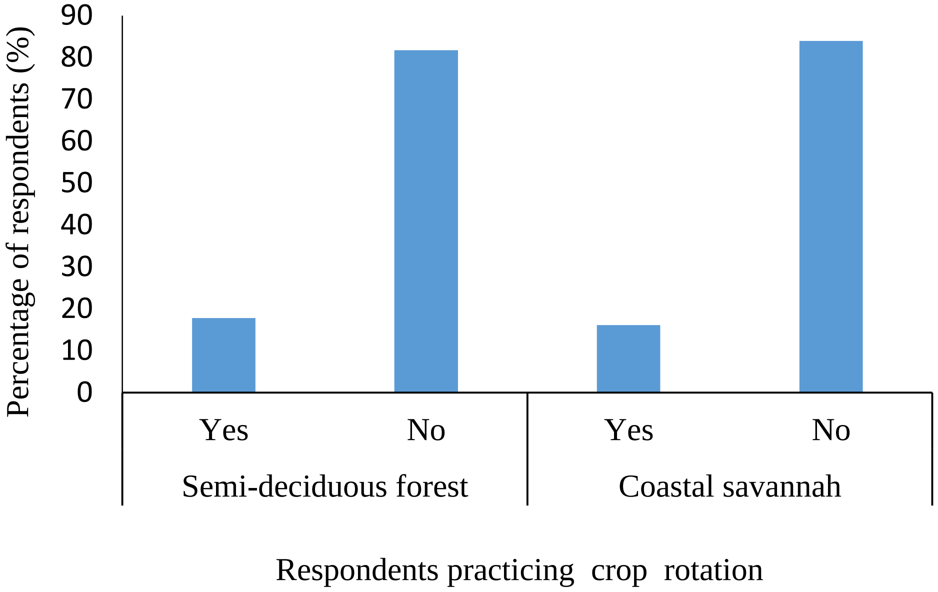


**Figure 3.11: Farmers practicing crop rotation**

Source: Field survey, Marfo-Ahenkora (2015)

***Livestock inventory of respondents***

The type and number of livestock kept by respondents are summarised in Table 3.17. Livestock was kept as a minor occupation for various purposes. From the table, it was observed that apart from the local fowl, majority of respondents kept sheep and goats.

**Table 3.37: Livestock holdings of respondents**

| Agro-ecological zone | Total Animals (range) | Cattle | Sheep | Goat | Pig | Local fowl | Exotic Fowl | Turkey | Duck | Rabbit | Grass cutter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Semi-deciduous forest | 1 -3 | 1 | 21 | 23 | 1 | 4 |  | 1 | 1 |  | 1 |
|  | 4 - 6 | 3 | 11 | 24 |  | 6 |  |  |  |  |  |
|  | 7 - 10 |  | 12 | 20 |  | 16 | 1 | 1 | 1 |  |  |
|  | 11 and above |  | 15 | 28 | 2 | 74 | 1 |  | 1 |  | 1 |
|  | Total | 4 | 59 | 95 | 3 | 1000 | 2 | 2 | 3 | 0 | 2 |
| Coastal savannah | 1 - 3 |  | 4 | 13 |  | 6 |  |  |  |  |  |
|  | 4 - 6 | 1 | 5 | 22 |  | 3 |  |  |  | 1 |  |
|  | 7 - 10 | 1 | 2 | 16 |  | 22 | 2 |  |  |  |  |
|  | 11 and above |  | 10 | 27 | 2 | 45 | 2 | 2 |  |  |  |
|  | Total | 2 | 21 | 78 | 2 | 76 | 4 | 2 | 0 | 1 | 0 |

Source: Field survey, Marfo-Ahenkora (2015)

A total of 59, 95 and 100 respondents keep sheep, goats and local fowls respectively in the SDFZ whilst 21, 78 and 76 respondents keep sheep, goats and local fowls respectively in the CSZ. Generally, livestock numbers were higher in the SDFZ than in the CSZ. About 71.7% of respondents in the SDFZ and 72.2% in the CSZ said they kept one form of livestock or the other.

### 3.4.2.5. Periods for maize planting and associated climate issues

#### *Month for planting maize*

Majority of respondents in the SDFZ (48.4%) and CSZ (55%) sow their major season maize in the month of April (Table 3.18). This was followed by the month of March where 24.4% and 22.8% of respondents from the SDFZ and CSZ respectively sow their major season maize. Only few farmers from the both the

SDFZ (4.4%) and CSZ (3.3%) plant their maize in June. The major season generally spread from March to May in both AEZ (Table 3.18).

Moreover, majority of respondents from the SDFZ (51.7%) and the CSZ (52.8%) sow their minor season maize in the month of September.

**Table 3.48: Months in which major and minor season sowings are done**

| Season of planting | Month | SDFZ | | CSZ | |
|---|---|---|---|---|---|
| | | Frequency | Percent (%) | Frequency | Percent (%) |
| Major | March | 44 | 24.4 | 41 | 22.8 |
| | April | 87 | 48.4 | 99 | 55 |
| | May | 41 | 22.8 | 34 | 18.9 |
| | June | 8 | 4.4 | 6 | 3.3 |
| Minor | July | 2 | 1.1 | 2 | 1.1 |
| | August | 82 | 45.6 | 70 | 38.9 |
| | September | 93 | 51.7 | 95 | 52.8 |
| | October | 3 | 1.7 | 13 | 7.2 |

Source: Field survey, Marfo-Ahenkora (2015)

## Climatic factors affecting maize production

The climatic factors affecting maize production in the perspective of the respondents have been summarised in Table 3.19. The results showed that in the SDFZ, drought (33.9%), late or early but unsustained rainfall (27.8%) and strong winds (22.8%) were the main climatic parameters which negatively impacted maize production in the two AEZs.

**Table 3.59: Climatic factors affecting maize production in the SDFZ and CSZ**

| Agro-ecological zone | Climatic factors | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Drought | 61 | 33.9 |
| | Flooding | 5 | 2.8 |
| | Strong winds | 41 | 22.8 |
| | Late/early but unsustained rainfall | 50 | 27.8 |
| | Drought & strong winds | 18 | 10.0 |
| | Flooding & strong winds | 5 | 2.8 |
| Coastal savannah | Drought | 31 | 17.2 |
| | Flooding | 4 | 2.2 |
| | Strong winds | 32 | 17.8 |
| | Late/early but unsustained rainfall | 56 | 31.1 |
| | Drought & strong winds | 35 | 19.4 |
| | Flooding &strong winds | 22 | 12.2 |

Source: Field survey, Marfo-Ahenkora (2015)

In the CSZ, late/early rainfall (31.1%), drought and strong winds (19.4%) and drought (17.2%) were the major parameters which influenced maize yield negatively (Table 3.20). Strong winds which causes lodging was listed as the third most important weather factor affecting maize production across the two AEZs.

### 3.4.2.6. Extension, credit, and record keeping

***Farmers access to extension services***

Majority of the respondents from the SDFZ (81.1%) and CSZ (76.7%) have access to extension services (Figure 3.12). Only 18.9% and 23.3% in the SDFZ and the CSZ respectively did not receive extension services.

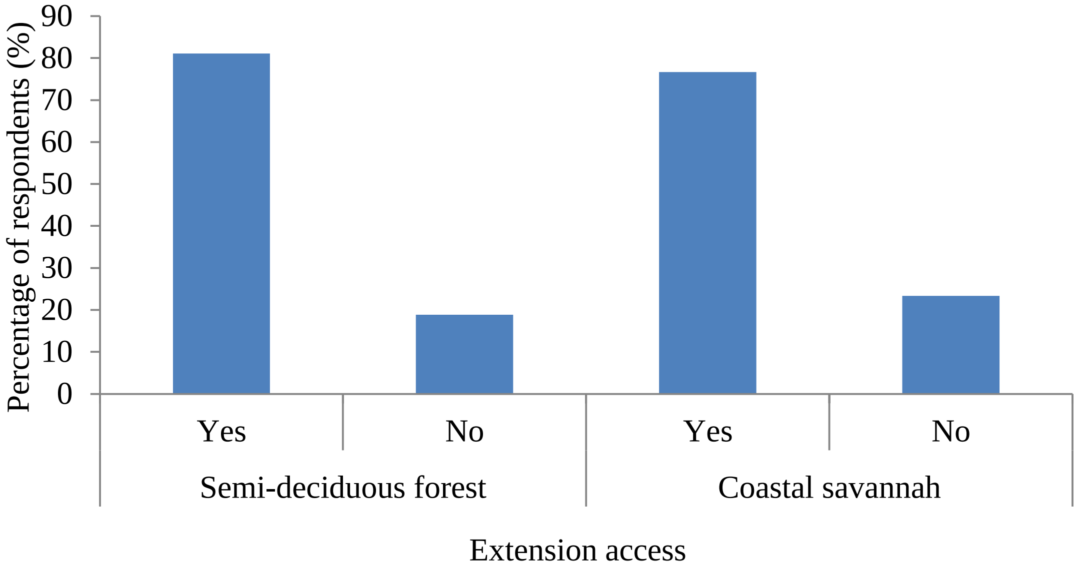


**Figure 3.22: Access to extension services**

Source: Field survey, Marfo-Ahenkora (2015)

***Importance of extension***

Respondents who had access to extension were asked to state the benefits or otherwise they received from extension personnel. Majority of respondents in the SDFZ (78.1%) and the CSZ (71%) gave technical advice as the benefit they derived from extension services (Table 3.20. Other farmers in the SDFZ (21.9%) and the CSZ (29%) said they benefited from transfer of modern technologies

**Table 3.20: Importance of extension**

| Agro-ecological zone | Importance of extension | Frequency | Percent (%) |
|---|---|---|---|
| Semi-deciduous forest | Technical advice | 114 | 78.1 |
| N = 146 | Transfer of modern technologies | 32 | 21.9 |
| Coastal savannah | Technical advice | 98 | 71.0 |
| N = 138 | Transfer of modern technologies | 40 | 29.0 |

Source: Field survey, Marfo-Ahenkora (2015)

***Access to credit for farming***

Only 21 out of the 180 respondents representing 11.7% had access to credit whereas the majority (159) representing (88.3%) had never had access to credit for farming in the SDFZ. In the CSZ, 15 respondents representing 8.3% had access to credits for farming whereas the majority (165) representing 91.7% had never had access to credit for farming (Figure 3.13).

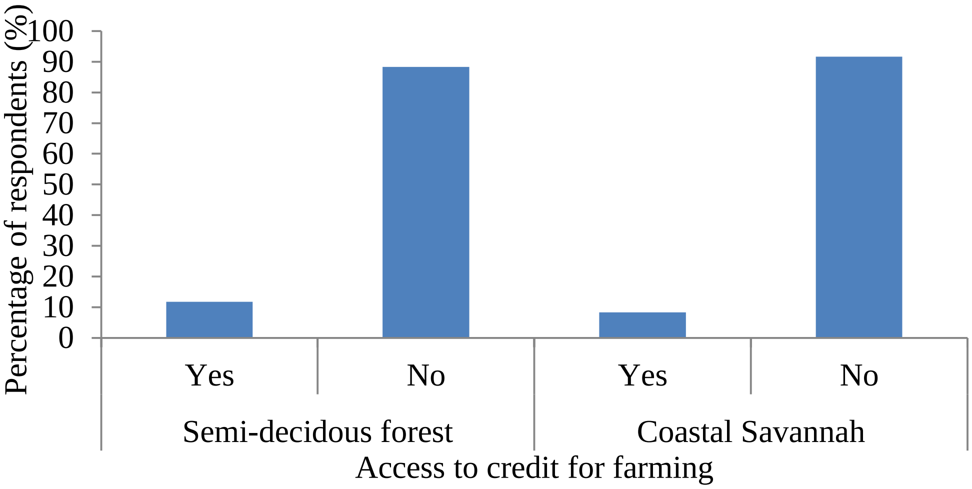


**Figure 3.33: Respondent’s access to credit for farming**

Source: Field survey, Marfo-Ahenkora (2015)

*Record keeping by farmer respondents*

Majority of respondents (53.9%) from SDFZ said they kept some form of records (written and memory) with 46.1% not keeping any form of records. On the other hand, 53.9% of respondents from CSZ said they do not keep records whiles 46.1% said they keep records.

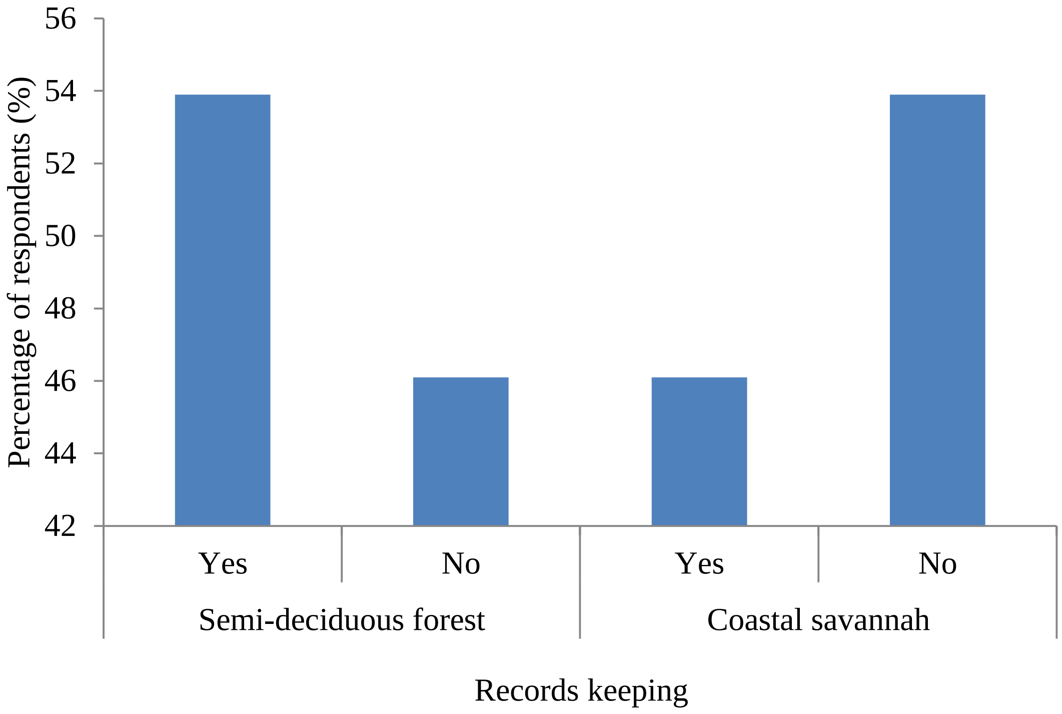


**Figure 3.44: Keeping of farm records by respondents from SDFZ and CSZ**

Source: Field survey, Marfo-Ahenkora (2015)

### 3.4.2.7. Associations between some socio demographic factors and other factors of production

*Gender and access to land*

Respondents' access to land with respect to gender had a significant ($P < 0.05$) relationship in the SDFZ but was not significant in the CSZ (Table 3.21).

**Table 3.21: Relationship between gender and access to land**

| Agro-ecological zone | Variable | Access to land | | Total (N=180) for each ecozone | Test | Interpretation |
|---|---|---|---|---|---|---|
| | Gender | Yes | No | | | |
| SDFZ | Male<br>Female | 21<br>25 | 94<br>40 | 115<br>65 | $\chi^2$ = 8.907<br>df = 1<br>P = 0.004 | ** |
| CSZ | Male<br>Female | 42<br>34 | 58<br>46 | 100<br>80 | $\chi^2$ = 0.005<br>df = 1<br>P = 1.000 | NS |

** significant (P<0.01); NS- not significant (P >.05);

Source: Field survey, Marfo-Ahenkora (2015)

***Total maize in hectares and gender distribution.***

The results showed a highly significant (P <0.01) relationship between total maize acreages and gender in both AEZs (Table 3.22). Female farmer respondents had smaller acreages (0.20 ha– 0.81 ha) in both AEZs with the male respondents dominating from 0.82 ha and above.

**Table 3.62: The relationship between total maize area in hectares and gender**

| Agro-ecological zone | Variable | Gender | | Total (N=180) For each ecozone | Test | Interpretation |
|---|---|---|---|---|---|---|
| | Total maize in hectares | Male | Female | | | |
| SDFZ | 0.20 – 0.81<br>0.82 – 1.62<br>1.63 – 2.43<br>> 2.43 | 29<br>40<br>34<br>12 | 31<br>29<br>2<br>3 | 60<br>69<br>36<br>15 | $\chi^2$ = 23.597<br>df = 3<br>P < 0.001 | ** |
| CSZ | 0.20 – 0.81<br>0.82 – 1.62<br>1.63 – 2.43<br>> 2.43 | 39<br>47<br>10<br>4 | 50<br>27<br>3<br>0 | 89<br>74<br>13<br>4 | $\chi^2$ =11.389<br>df=3<br>P = 0.006 | ** |

*more than 20% of expected cell counts are less than 5 in the CSZ.
** significant (P <0.01)
Source: Field survey, Marfo-Ahenkora (2015)

### *Access to credit facility and fertilizer use*

The results show that respondents' access to credit with respect to fertilizer use was not significant (P > 0.05) in the SDFZ but was significant (P < 0.05) in the CSZ (Table 3.23).

**Table 3.73: The relationship between access to credit facility and fertilizer use**

| Agro-ecological zone | Variable | Fertilizer use | | Total (N=180) | Test | Interpretation |
|---|---|---|---|---|---|---|
| | Access to credit | Yes | No | | | |
| SDFZ | Yes | 11 | 10 | 21 | $\chi^2 = 0.254$ | |
| | No | 74 | 85 | 159 | df = 1 | NS |
| | | | | | P = 0.648 | |
| CSZ | Yes | 11 | 4 | 15 | $\chi^2 = 5.308$ | |
| | No | 70 | 95 | 165 | df = 1 | * |
| | | | | | P = 0.029 | |

*significant (P<0.05); ** significant (P<0.01); NS- not significant
Source: Field survey, Marfo-Ahenkora (2015)

### *The relationship between the respondents' level of education and other factors of production*

It was observed that the level of education of the respondents in the SDFZ had no significant relationship with fertilizer use (SDFZ; $\chi^2 = 2.519$, df =2, P = 0.290), adoption of row planting (SDFZ; $\chi^2 = 1.699$, df =2, P = 0.429), access to credit (SDFZ; $\chi^2 = 0.719$, df=2, P = 0.728) and access to extension services (SDFZ; $\chi^2 = 3.316$, df = 2, P = 0.208). Similarly in the CSZ, farmers' level of education had no significant relationship with their fertilizer use ($\chi^2 = 1.667$, df =2, P = 0.433), adoption of row planting ($\chi^2 = 0.901$,df =2,P = 0.671), access to credit facilities ($\chi^2 = 1.335$ df=2, P = 0.577) and access to extension services ($\chi^2 = 0.071$, df = 2, P = 1.000).

### *Farmer associations and access to credits*

The interaction between access to credit and belonging to a farmer association was not significant (P=0.243) in the SDFZ but was significant (P=0.032) in the CSZ (Table 3.24).

**Table 3.84: The relationship between belonging to farmer association and access to credit**

| Agro-ecological zone | Variable | Access to credits | | Total (N=180) | Test | Interpretation |
|---|---|---|---|---|---|---|
| | Farmer association | Yes | No | For each ecozone | | |
| SDFZ | Yes<br>No | 15<br>6 | 90<br>69 | 105<br>75 | $\chi^2 = 1.677$<br>df = 1<br>P = 0.243 | NS |
| CSZ | Yes<br>No | 11<br>4 | 72<br>93 | 83<br>97 | $\chi^2 = 4.880$<br>df = 1<br>P = 0.032 | * |

*significant (P<0.05); NS- not significant
Source: Field survey, Marfo-Ahenkora (2015)

### *Farming as main occupation and fertilizer use*

There was no significant relationship between the two variables in the SDFZ ($\chi^2$ = 2.143, df = 1,P = 0.188) and CSZ ( $\chi^2$ = 0.081, df = 1, P = 0.851).

### *Row planting and fertilizer use*

Table 3.25 presents the relationship between respondents' practicing row planting and fertilizer use. There was a highly significant (P< 0.01) relationship between row planting and fertilizer usage in both AEZs (Table 3.25).

**Table 3.95: Relationship between row planting and fertilizer use**

| | Variable | Fertilizer use | | Total (N=180) For each ecozone | Test | Interpretation |
|---|---|---|---|---|---|---|
| | Row planting | Yes | No | | | |
| SDFZ | Yes<br>No | 74<br>11 | 62<br>33 | 136<br>44 | $\chi^2 = 11.537$<br>df = 1<br>P = 0.001 | ** |
| CSZ | Yes<br>No | 76<br>5 | 61<br>38 | 137<br>43 | $\chi^2 = 25.422$<br>df = 1<br>P < 0.001 | ** |

** significant (P < 0.01)

Source: Field survey, Marfo-Ahenkora (2015)

## 3.5. Discussion

### 3.5.1. Socio-economic characteristics influencing maize production

The socio-economic factors discussed include age, gender, education level of farmers, farm size, land tenure issues, extension service, credit acquisition, and membership of farmer associations. The observed high percentages recorded for the age range, 41 to above 60 years which was a less active service group were relatively high considering the fact that this older generation were not fast adopters of technologies and prefer to hold on to their old and entrenched farming practices. This could have implications for technology adoption in the study areas. Coelli (1996) reported that, older farmers could be more traditional and conservative and show less willingness to adopt new practices.

The observed male dominance in maize farming in both AEZs was probably because farming was seen as men's job in most farming communities although women play important roles such as helping with the planting, harvesting, gathering of produce on the farm, shelling and sale of produce. Women's labour contribution in maize production was therefore significant in the study areas. Similar observations were made by Morris et al. (1999), who reported that in Ghana women contribute an important proportion of the overall labour requirements in the farm, and exercise complete discretion over the disposal of the harvest. It has also been reported in Kenya that, men dominate maize farming and yet women provide the greatest labour (World Bank, 2006). The significant relationship between gender and access to land observed in the SDFZ was in agreement with the report by Razavi, (2003) who observed that tenure systems tend to be gender bias with many land titles favouring men as the 'family head'. This is probably the reason why majority of male farmers in the two AEZs had bigger farm sizes than their female counterparts.

The high percentage of respondents with only basic education in these study areas may be disadvantageous to agricultural productivity in that, it is sometimes difficult for illiterate farmers to appreciate and adopt innovations in agriculture. Oyekale and Idjesa (2009) confirmed that extremely low level of education could affect the level of technology adoption and skills acquisition among farmers. Simiyu (2014) also established that educational level of farmers influences adoption and that farmers with either university or postgraduate level of education easily adopt new technology compared to those with less education. The non-significant relationship between level of education and other factors of production such as fertilizer use, row planting, access to credit and extension services observed in this study, was in contrast to the findings of Rad et al (2010) who observed that, level of education enhances active participation in innovation and that education enhances the farmers' ability to access productive resources such as credit, land, extension and labour. The results of the current study was probably because majority of respondents had only basic education and only few respondents had gone up to the Senior High School level and so level of education did not influence their decision to use fertilizer, plant in rows, access credit and access extension services. Tripp et al. (1987) also reported that there was no effect of education on adoption and that, for those farmers with two years or less of schooling; adoption rates were equivalent to those of the general population.

Majority of farmers had been growing maize for a longer time and the assumption is that they would adopt some sustainable farming practices such as use of fertilizer, manure, and crop rotation but this was not so. The implications of these results are that the majority of farmers have acquired many years of farming experience however, majority of them were not literate enough to understand and/or implement modern systems of farming and adopt new technological innovations in agriculture to enhance productivity as corroborated by Kluste et al. (2013).

The observed low percentage of respondents who had maize farms above 2.43 hectares in the SDFZ (8.3%) and the CSZ (2.2%) could be due to the fact that majority of farmers in the CSZ acquired land for farming through lease/hiring. The cost of hiring could be prohibitive to the smallholder farmers and hence they most likely went for smaller farm sizes whose rent they could afford. The sizes of their land holdings for maize confirm that they were smallholder maize farmers. Small land holdings have the potential to limit the farmers in so many ways. For instance, Hussain and Thapa (2012) reported that, farmers with small landholdings have limited access to agricultural credit. The results revealed that generally, farmers do not have access to credit facilities for their farms. Lack of finances for farming was one of the major problems faced by respondents in the study areas.

Most of the participants at the FGD indicated that the land tenure terms had not affected their soil fertility management activities. This accession was not entirely true from the researcher’s assessment of the situation on the ground. The land tenure systems affected their soil fertility management indirectly. This was because the landowners wanted to benefit fully and all the time from their land so they did not allow their lands to lie fallow for both sharecropping and lease. In the case of sharecropping, land owners dictated what to plant and so farmers cannot do rotations easily. Adjei-Nsiah (2006) however revealed that there was a link between tenure insecurity among migrant farmers especially, and limited attention for regeneration of soil fertility such that, tenant farmers in the Wenchi district began intensive cultivation of the land without sufficient soil fertility restoration measures in order to maximize profits after they started paying for the land. Ownership of land can therefore influence agriculture productivity, because farmers who do not own land can be adamant in developing and/or maintaining the land (Randela, 2005). Farmers on family lands who could afford to let the land lie fallow also indicateded that the fallow periods have been shortened considerably to between 1-2 years due to pressure on the lands. According to Fresco (1986), farmers tend to react to pressure on land by shortening the fallow periods as observed in this current study. Accessing land for farming was generally a challenge for the communities in the CSZ than in the SDFZ.

The percentages recorded for extension access for this study was good although majority of respondents had access to extension once every three months and this seemed not sufficient for good extension impact. Addai (2011) reported that regular farmer contacts with extension agents facilitated the adoption of modern technologies. Yaron et al. (1992) also reported that access to extension services was critical in promoting adoption of modern agricultural production technologies.

The significant relationship observed between farmer associations and access to credit in the CSZ was also reported by Tetteh (2013) who observed a significant relationship between farmer group membership and smallholder farmer‘s access to credit and inputs. Farmer associations have sometimes proved useful to farmers in situations like acquisition of farm inputs on hire purchase basis or access to markets. Seleka (2011) reported that when households market their produce in groups, there is a higher chance of participating in either formal or informal markets thus, group participation encourages market penetration among smallholder farmers who find it difficult individually to gain market access.

The relatively high number of respondents indicating record keeping could be because records kept in memory was also regarded as record keeping. Ultimately, use of written records has to be encouraged among smallholder farmers. Devonish et al. (2000) observed that more than half (57%) of a total of 160 farmers interviewed were obtaining credit due to the fact that they were keeping farm records.

### 1.5.2 Technical characteristics influencing maize production

The observed popularity of Obatanpa as the improved maize variety of choice in both AEZs was upheld by Ragasa et al. (2013) who through a nationwide survey observed Obatanpa to be the dominant improved maize variety planted. The local white maize was the most popular variety used in both the SDFZ and CSZ. This result is in agreement with Odendo et al. (2001) who reported that nearly 80% of the farmers in Africa predominantly grow local maize varieties partly because they can recycle seeds for many seasons, whilst about 20% grow improved varieties, often in addition to the local varieties. In the current study, about 78% (SDFZ) and 70% (CSZ) of farmers said they cultivate local varieties in addition to Obatanpa. In spite of the release of newly improved maize varieties, most farmers in the study areas still preferred their local variety even though the yield of local varieties have been observed to be low (Kpotor, 2012) and this has implications for sustainable maize production.

The use of farmer saved seed (FSS) which was very common in the study areas was not the best practice. The FSS included seeds from both the local varieties and Obatanpa. The probability that the original Obatanpa germplasm has been contaminated is very high because it has been reused for several years. Ragasa et al. (2013) had indicated that the OPVs could be used for at most three cropping seasons and then new seeds should be obtained but this was not the case in the study areas. The authenticity of Obatanpa seeds sold in the agro-input shops should be a source of concern since there is lack of an effective system for seeds and regulation of the seed sector is also poor in Ghana (Tahirou et al., 2009). Poor seed policy environment ranked third among other constraints in both Nigeria and Ghana in a survey conducted by Tahirou et al. (2009). Alhassan and Bissi (2006) also estimated that only 10% of the seeds planted in the country were certified seeds provided by the formal sector and the rest were sourced from the informal seed sector. Farmers do not readily buy improved seeds because some of them cannot afford to pay for the price of certified seeds. A further disincentive to the purchase of improved seeds is the farmers' inability to buy the inorganic fertilizer that is needed for the improved seeds to reach the full yield potential (Tahirou et al., 2009).

Grain yields were considerably low for majority of respondents in the study areas. One of the reasons for their low yields could be due to the use of FSS (farmer saved seeds). Continuous use of FSS (especially of improved varieties) by respondents in the study areas has repercussions for sustainable maize production. Farmers in the current study areas had not heard (in some cases) about newer varieties or did not have access to the seeds. The use of newer improved maize varieties especially those with drought tolerant qualities such as Omankwa, Aburohema and Abontem released by CSIR-Crops Research Institute (CRI) in 2010 have to be introduced to maize farmers through on-farm demonstrations by extension agents and researchers. Drought tolerant maize varieties can make significant increase in maize yield and favour poverty reduction in sub-Saharan Africa (La Rovere et al., 2010).

The age old practice of slash and burn for land preparation which was the most common land preparation method has a lot of disadvantages including loss of organic matter, loss of moisture from the soil, death of some beneficial soil micro-organisms and loss of volatile nutrients from the soil (Cox et al., 2006; Afful, 2015). The continuous use of slash and burn method is part of the reasons why soil productivity is declining in these zones. What is being advocated is spot (controlled) burning where the big twigs/branches on the farm could be gathered at some few locations (usually at the edge of the farm) and burnt leaving the leaves and other residues on the land to decompose. The observed most popular land preparation method of slash and burn and/or herbicide application has also been reported by Afful (2015) who observed that 95% of respondents prepare their land either by slash and burn or slash/burn/herbicide in the Tano South district of the Brong-Ahafo region. These results are however not in agreement with studies done by Mensah-Bonsu et al. (2011) who reported that about half of farmers interviewed in the middle of Ghana practice no-burn during land preparation, and 38% practiced zero tillage. Ragasa et al. (2013) reported that plots under slash-and-burn had significantly lower yields compared with plots that were ploughed. In the current study, only few farmers (6.1%) ploughed with tractor in both AEZs.

Herbicide use which was very popular in the study areas seem to be taking over as the most prominent weed control method for maize cultivation. The availability of selective herbicides for maize which makes weed control easy for the farmers without any damage to the maize has increased the use of herbicide for weed control in maize farms. The challenge had been the proliferation of inferior or substandard herbicides on the market and the use of the correct dosage (FGD) to avoid long term negative effects on the soil and human health.

The observed high cost and transportation of the fertilizer from the district capitals to the communities which was a challenge to farmers in the study area, was also observed by Ragasa et al. (2013) who reported that the intensity of fertilizer use was associated with proximity of the farm to the local source of fertilizer. Yawson et al. (2010) observed that among other factors, the lower patronage of fertilizers in the area (Central region) could be attributed to the low scale of production, lack of marketing structures for the farmers as well as higher transaction costs emanating from the need to transport fertilizer. For those who did not apply fertilizer in the SDFZ, the perception among the farmers was that their soils were already fertile. This could be the reason why majority of the farmers in the SDFZ use low quantities of fertilizer (61.8 kg ha$^{-1}$). Mugwe et al. (2009) reported that majority of smallholder farmers cannot afford mineral fertilizers, and those using fertilizer hardly use the recommended rates. The observation that majority of respondents from CSZ use higher quantities of fertilizer on their farms compared to their counterparts in the SDFZ was also reported by Ragasa et al. (2013). Across the AEZs, fertilizer usage was generally low and this has implications for sustainable maize production.

The reported low percentage of farmers (6.1% in SDFZ and 4.4% in CSZ) using manure for their crop farming was in agreement to observations by Ragasa et al. (2013) who reported that only 3% of land under maize cultivation is applied with animal manure. Mensah-Bonsu et al. (2011) however reported that animal manure was applied by 17% of farmers they interviewed in the middle section of Ghana. This percentage was on the high side compared to the current study and also the study by Ragasa et al. (2013). Even though the farmers kept livestock, they did not use farmyard manure for crop production. Composting of manure for maize production in these communities has great potential. Cultivation of legumes was generally not part of the cropping systems in the study areas. The predominant practice of continuous cropping and the limited adoption of soil fertility management practices such as use of fertilizer, manure, crop rotation and planting of legumes in the study areas, put a lot of nutrient stress on the farm lands of these smallholder farmers. Generally, from the farmer interactions made in these communities, most of the farmers did not make enough soil fertility replenishment efforts.

The observation in this current study where majority (75.6%) in the SDFZ and (76.1%) CSZ of respondents did row planting is in agreement with a survey by Ragasa et al. (2013) who reported that about 53% of respondents plant in rows but the actual plant spacing being used by farmers and number of seeds per hill seemed to differ from research and extension recommendations. On the other hand, Afful (2015) indicated that 82% of the respondents sow randomly. This observation is in contrast with this current study. The significant relationship between row planting and fertilizer usage observed may be due to the fact that row planting allows for easy farm operations including fertilizer application. Tripp et al. (1987) also reported that if maize is planted in rows, it is much easier to apply the correct amount of fertilizer and that row planting is more likely to be associated with fertilizer use as observed in this current study.

A transect walk through some of the farms surveyed in the study areas, revealed that farmers who did row planting were using relatively wider spacing than the recommended one and those who did no row planting also use wider spacing giving reasons such as low soil fertility for their practice. Wide planting distances was seen as a means of combating declining soil fertility in the communities. This confirms the assertion by Buah et al. (2009) that, traditionally, farmers use low plant densities as their adaptation to low soil fertility and soil moisture, and a means of minimizing risk during drought.

### 3.5.2. Biophysical characteristics influencing maize production

The biophysical factors in this study focused on climate variation and erratic rainfall patterns. The change in rainfall pattern which has led to some changes in the planting times was a source of worry to the farmers since they sometimes had to plant 2 or 3 times in a season when rainfall is too early or too late. Participants from the FGD agreed that they were experiencing changes in weather conditions. It was evident from the results gathered that, the majority of farmers depended on rainfall for farming because late or early rainfall and drought were the major climatic problems they encountered in their farming activities. This established the assertion that maize production was mainly under rainfed conditions in Ghana (MoFA, 2011). Keith et al. (2010) similarly reported that, extreme weather events that cause crop failure are prolonged droughts, floods, strong winds and heat waves. Strong winds which causes lodging was listed as the third most important weather factor affecting maize production across the two AEZs.

The inability of farmers in the study area to practice various technologies they had learnt was attributed to lack of financial resources, unfavourable land tenure terms, unavailability of labour and also non-appreciation of benefits of some of the technologies. Adjei-Nsiah et al. (2006) made similar observations that, utilization of technology by farmers depend also on socio-economic factors such as accessibility to resources including land, cash, credit, labour and food security.

### 3.6. Chapter summary

- The study revealed that adoption of sustainable production practices (such as use of improved varieties, soil amendments and good agriculture practices) for maize was influenced greatly by socio-cultural, socioeconomic, technical as well as biophysical factors in the study areas of the SDFZ and CSZ.
- Unpredictable weather conditions, unstable market prices and risk of crop failure were observed to be some of the major reasons why most farmers did not want to invest in new technologies.
- Lack of access to credit for farming which in turn affects farmers' ability to purchase inputs, expand production area and acquire labour was a major problem in all the study areas.
- Herbicide use on maize was very popular with all kinds of formulations on sale in the study areas.
- Land preparation was basically the slash-and-burn method which could affect soil productivity.
- Majority of farmers were not practicing any soil fertility management in spite of the fact that most of them were engaged in continuous cropping.

- Low plant population was observed even for those who had adopted row planting.
- Use of local varieties and farmer saved seed was widespread in the study areas coupled with lack of certified seeds for newly released varieties.
- Obatanpa was the most popular improved maize variety used by the farmers.
- The importance of grain quality in storage, cooking qualities and market preference were recognized as important factors for acceptance and sustained use of new maize varieties.
- Unfavourable land tenure arrangements were found to contribute to inadequate soil fertility management as well as low incomes for farmers.
- The proliferation of inferior or substandard herbicide products on the market was a serious challenge.
- Inadequate tractor service for ploughing especially for the coastal communities was hampering early land preparation.

# CHAPTER FOUR

# PERFORMANCE OF THREE MAIZE VARIETIES UNDER DIFFERENT SOIL FERTILITY MANAGEMENT SYSTEMS IN SMALLHOLDER FARMS IN TWO AGRO-ECOLOGICAL ZONES OF GHANA

## 4.1. Introduction

Maize is the most widely produced and consumed cereal crop in Ghana, and is grown by the vast majority of rural households in all the ecological zones of the country (Fening et al., 2011). However, the productivity is low and cannot meet current demands due to a myriad of challenges including low inputs use (improved seeds and fertilizer), inherently poor soils due to poor soil management practices, low manure use, inadequate crop rotation, continuous cropping, little or no fallow periods and unfavourable climatic conditions. Zingore et al. (2007) reported that there are renewed efforts to support the predominantly subsistence farmers to intensify crop production mainly by increasing the use of fertilizers and improved crop varieties.

A number of improved maize varieties have been released over the years (Ragasa et al., 2013) to enhance sustainable production of the crop. In spite of this, the smallholder farmers continue to use their local varieties whose yields are said to be very low and are therefore not recommended (Kpotor, 2012). It is therefore important to introduce high yielding improved maize varieties to farmers in order to improve maize productivity.

Maize yields have been reported to vary depending upon variety, location, soil nutrient status and application of fertilizers (Kpotor, 2012). In order to realise the full potential of any variety, good agronomic practices and improved soil fertility management are prerequisites. Boniphace et al. (2015) also reported that increased use of external inputs (improved seeds, fertilizers and agro chemicals) alongside organic soil fertility enhancing practices are crucial in addressing the technical change needed for sustainable smallholder agricultural growth in Africa. In an effort to sustain crop productivity, it is essential to explore alternative soil fertility replenishment strategies such as use of manure which will be more affordable to smallholder farmers.

Most rural households in southern Ghana, keep sheep and goats as part of their farming systems. Although goat manure is readily available in most smallholders' homesteads, its use as organic manure for crop production has received little research attention in southern Ghana. Manure from these small ruminants can serve as a rich source of organic manure for crop production and for continuous land use. Uwah and Eyo (2014) reported that goat manure significantly increased growth and yield of sweet maize in south eastern Nigeria. However, there is a dearth of information on effect of goat manure and its combination with inorganic fertilizer on maize production in the coastal savannah and semi deciduous forest AEZS of Ghana.. Combined use of manure and inorganic fertilizer is an intervention geared towards reducing cost of external inputs and increase maize production in a sustainable manner.

## 4.2. Objective

The objective of this study was to assess the performance of three maize varieties under different soil amendments (goat manure, inorganic fertilizer and their combination) in smallholder farm environments in two agro-ecological zones in Ghana.

## 4.3. Materials and methods

The study was carried out as researcher managed researcher implemented on-farm trials. Field experiments were conducted in the coastal savannah (CSZ) and semi deciduous forest (SDFZ) agro-ecological zone (AEZ) in three communities per zone. The study was carried out between April and August in the major season of 2017. The experiments were carried out as participatory action research. Some selected farmers were actively involved in this study from land preparation, field layout, planting, weed management and data collection to harvesting of the maize. At each experimental site, one dedicated farmer was chosen and together with the agricultural extension agent in the community, they helped with supervision of the farm as well as data collection.

### 4.3.1. Description of study sites

#### *4.3.1.1. Location and soil type*

The experiments were conducted in six communities (three per each AEZ). The three sites in the CSZ were located at Awutu Bontrase, Akufful Krodua and Awutu Ofaso, all in Awutu Senya district of the Central Region of Ghana. The distance between two successive communities in this zone was about 7.5 km on the average. The three sites in the SDFZ were Okyerekrom, Ahenkorase and Otareso/Mankrado communities in the Akuapem North district in the Eastern Region of Ghana. The distance between two successive communities in this zone was about 10.5 km on the average.

All the experimental fields had been used for continuous cropping of maize and cassava over the years. The locations of the farms are represented in Figure 4.1

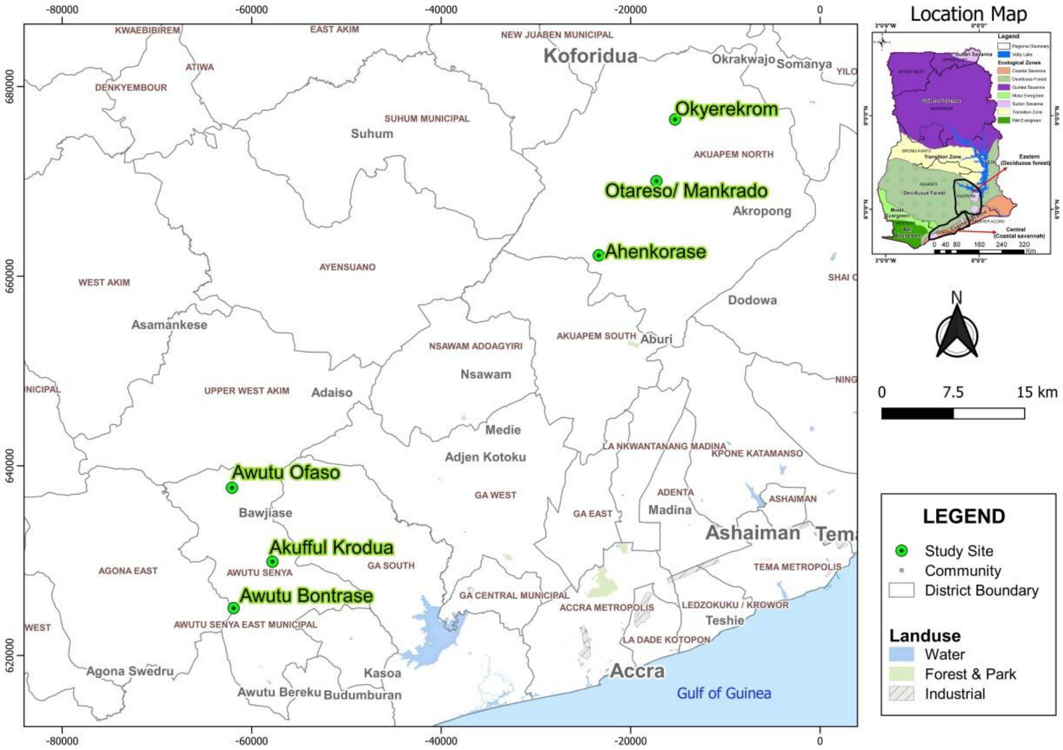


**Figure 4.1 A section of the map of Ghana showing the study areas and the six experimental sites in the Eastern and Central regions of Ghana.**

### 4.3.1.2. Climate

All the experimental sites have a bimodal rainfall pattern. Generally, the major rainy season starts in April and ends in July while the minor season begins in September and ends in November with a dry spell in August. There is a dry season from mid-December to March. Temperatures are relatively high with a monthly mean of between 21and 34 $^{o}$C. Rainfall for the forest zone ranges from 990 mm to 1650 mm and the Coastal savannah AEZs receives less than 1000 mm annual precipitation according to Ghana Meteorological Agency (2017). The mean relative humidity ranged from 70% to 81% in the CSZ and 70% to 90% in the SDFZ.

The soils on the fields where the farms were situated in the coastal savannah and semi deciduous forest agro-ecological zone have been classified in Table 4.1. Other specific information on the communities in terms of climate, vegetation and soils have been outlined under their respective district profiles (Chapter 3).

**Table 4.1: Experimental sites, their soil classification and geographic location**

| Community | FAO/UNESCO classification (FAO,1988) | GPS coordinates |
|---|---|---|
| **Coastal savannah AEZ** | | |
| Awutu Bontrase | Dystric Leptosols | $5^0$36'19.5"N $0^0$33'22.1"W |
| Akufful Krodua | Dystric Leptosols. | $5^0$38'56.9"N $0^0$31'9.5"W |
| Awutu Ofaso | Haplic Lixisols | $5^0$43'7.8"N $0^0$33'27.6"W |
| **Semi-deciduous forest AEZ** | | |
| Okyerekrom | Dystric Fluvisols | $6^0$3'57.7"N $0^0$8'15.1"W |
| Ahenkorase | Umbric Leptosols | $5^0$56'16.7"N $0^0$12'35.5"W |
| Otareso/ Mankrado | Cambic Arenosols | $6^0$0'28.5"N $0^0$9'18.7"W |

The classification was done by the CSIR-Soil Research Institute, Accra Centre.

### 4.3.2. Field Experiments

#### *4.3.2.1. Soil Sampling/analysis*

Soil samples from 0-15 cm and 15-30 cm depth were collected from different locations of each farm with the help of an auger before and after the experiments (after minor season harvest). These were mixed together to form a composite soil sample and then sub-samples for each site taken to the laboratory for analysis. Soils were air- dried and passed through 2 mm sieve to remove large particles, debris and stones. The soils were analyzed for physical properties mainly particle size analysis (i.e % sand, % silt, % clay) by the use of the pipette method as described by Gee and Bauder (1986). Chemical properties of the soils such as, pH, total nitrogen, available phosphorus (P), organic carbon/matter and exchangeable cations (K, Na, Ca and Mg) were ascertained. In addition, total acidity, total exchangeable bases, effective cation exchange capacity (ECEC) and percent base saturation were also determined. Soil reaction (pH) was measured in 1:2.5 soil: water suspension. Total nitrogen in the samples was determined by the modified Kjeldahl method (Bremner, 1996). Available phosphorus contents in the soils were extracted by Bray's P1 solution and measured by a spectrophotometer (Bray & Kurtz, 1945). Organic carbon was determined by the wet oxidation method of Walkley and Black (1934). Exchangeable bases were extracted with 1.0 M ammonium acetate solution at pH 7.0. Sodium and potassium contents in the extract were determined by flame photometry while calcium and magnesium were by titration. Thomas (1982) method was used for the determination of exchangeable acidity. Effective Cation Exchange Capacity (ECEC), Base and Cation percentages were by calculation.

#### *4.3.2.2. Land preparation*

The land was cleared with machete and the stumps of the few available shrubs were removed with a mattock. Pre-emergence weedicide (glyphosate) was applied at a rate of 1.5 kg ha$^{-1}$ two weeks before sowing.

#### *4.3.2.3. Goat manure characterization*

To ensure reliability of manure supply, the goat manure which was applied as a soil fertility amendment was obtained from the CSIR-Animal Research Institute farms, Accra-Ghana. The nutrient content of the goat manure was analyse by sampling ten handfuls of the manure from each compost pit which was then bulked to form a single composite sample. The composite sample was air-dried, thoroughly mixed and ground to pass through a 2 mm sieve. Sub-samples were then collected for chemical analysis (IITA, 1982) prior to application on the field. The goat manure was composted for four months to ensure ample decomposition before application.

#### *4.3.2.4. Experimental materials*

Three varieties of maize consisting of one landrace (Ahomatea-Local variety) and two improved open pollinated varieties (OPV) were used in this study. The improved OPV (Omankwa and Obatanpa) were obtained from the CSIR-Crop Research Institute, Kumasi, Ghana while the landrace “Ahomatea” was supplied by the farmers in the locality. Obatanpa was used in this study because of its popularity among the farmers. Omankwa was also used because of its unique attributes (drought tolerant and early maturing). The characteristics of the varieties used are summarized in Table 4.2.

**Table 4.2: Attributes of maize varieties used for the experiments**

| Variety | Year of release | Attributes |
|---|---|---|
| Omankwa | 2010 | Early maturing; Drought tolerant; Striga tolerant; quality protein maize (QPM); OPV |
| Obatanpa | 1992 | Intermediate maturing; Quality protein maize; tolerance to pests and diseases (blight, rust, streak, stem borer) ; OPV |
| Landrace (Local variety) | unknown | Late maturing; Open pollinated variety |

Source: Ragasa et al. (2013).

### *4.3.2.5. Experimental design and treatment*

Maize was sown using a planting distance of 0. 80 m x 0.40 m. There were eight rows measuring 5.6 m long. Each plot measured 6.4 m x 5.6 m. Sowing was done between 20th and 25th April, 2017 in both agro-ecological zones. Three seeds per hill were sown and later thinned to two plants per hill at 14 days after sowing, giving a total plant population of 62,500 plants per hectare. There were three different soil amendments and a control and three maize varieties giving a total of 12 treatment combinations in the major season of 2017. Details of the soil amendments applied have been presented in Table 4.3. These factorial combinations of the treatments were laid out in a randomized complete block design with four replications at each locality. In all, 48 plots were laid out at each site.

**Table 4.3: Soil Amendments applied**

| Soil Amendment | Rate of application | Code for treatments |
|---|---|---|
| NPK fertilizer ( 15-15-15) + N (Urea) | NPK 250 (kg $ha^{-1}$) + Urea 125 (kg $ha^{-1}$) | Fertilizer |
| Goat manure ( GM) | 5.0 t $ha^{-1}$ GM | Manure |
| 50% GM + 50% NPK + 50% Urea | 2.5 t $ha^{-1}$ GM + NPK 125 kg $ha^{-1}$ + Urea 62.5 kg $ha^{-1}$ | Fert + manure |
| No fertilizer, No manure | None | Control. |

Source: Field data, Marfo-Ahenkora (2017)

The NPK (15-15-15) + Urea at the rate given in Table 4.3 gave 95% N, 37.5% P and 37.5% K. The selected soil amendments were applied in the major season. Manure was applied by spot placement a week before planting. Treatments with fertilizer received NPK fertilizer at 2 weeks after sowing (WAS) by placing it at the side of the seedling and then side dressed with urea at 4 WAS. After application, the soil was turned lightly to incorporate the fertilizer to avoid exposure to direct sunlight and surface runoff.

#### *4.3.2.6. Weed management*

Weeds were controlled at 4 and 8 WAS with Nicosulfuron 40 (Nicoking) a post emergence herbicide for maize at the rate of 1.5 L ha-$^{1}$.

### 4.3.3. Data collection

Rain gauges were installed in all the experimental sites to record the amount of rainfall on the farm throughout the study period. Mean temperatures were sourced from the Ghana Meteorological Agency.

Data on maize phenology, growth, yield, and yield components were taken throughout the major growing season.

### *4.3.3.1. Phenology records*

Data were recorded at all the experimental sites. The number of days to 50% emergence was recorded as the number of days 50% of the seedlings emerged on the plots. Two weeks after sowing, maize seedlings from the plot were counted and their percentage emergence per treatment was calculated. Days to 50% anthesis was recorded as the number of days when 50% of the plants had tasselled n and days to 50% silking, as the number of days from planting to when 50% of the plants had emerged silks. The anthesis-silking interval (ASI) was then determined as the difference between days to 50% silking and 50% anthesis.

The number of days to physiological maturity was counted as the number of days maize grains showed a black layer at the tip or base of the kernel. This black layer signifies that the kernel had reached physiological maturity.

### **4.3.3.2. Growth measurements**

The growth data collected during the field experiment were plant height, stem girth, number of leaves, leaf area and then leaf area index was calculated. Growth data was collected at 2 weeks intervals starting from 5 weeks after sowing (WAS) to 11 WAS. In the SDFZ, data were collected between 26th May, 2017 and 7th July, 2017, whilst in the CSZ, data collection occurred between 30th May, 2017 and 11th July, 2017.

Ten maize plants were randomly selected from the middle rows of each treatment plot and tagged for growth measurements at 4 WAS. The selection of plants was from the six middle rows.

### *Plant height*

Plant height was measured as the distance from the base of the stem at soil level to the point of attachment of the upper most leaf using a graduated pole. The mean from the ten plants were then determined to obtain the mean height per plant in each of the 48 plots per site.

### *Stem girth*

The stem girth was measured at 0.40 m height from the soil level for 5 WAS and 1.0 m height from 7 to 11 WAS using a piece of twine around the stem and the actual measurements were determined on a tape measure in centimetres for each plot and the mean values for the treatments determined.

### *Leaf area*

Leaf area was also determined using destructive analysis. Two plants were randomly selected from the 2nd and 7th inner rows on each plot at 5, 7, 9 and 11 WAS for the determination. The length and the widest part of each green leaf and leaves with more than 50% of lamina being green from each plant was then taken with a tape measure. The product of the length and maximum leaf width of each leaf was multiplied by a constant (0.75) to give the area for each leaf (Fageria et al., 2006).

The total leaf area per plant was obtained by summing up the leaf area of each plant and then the mean leaf area per plant was then determined for each treatment.

### 4.3.3.3. Yield parameters

Harvesting of Omankwa, Obatanpa and landrace (local variety) were done on 27th July, 17th August and 23rd August, 2017 respectively in the SDFZ. In the CSZ, Omankwa, Obatanpa and the landrace (local variety) were harvested on the 31st July, 24th August and 29th August, 2017 respectively. Harvesting was done when all the plants in the plots were dried with the cob husk turning light brown straw coloured. Plants were sampled from an area of 1 m x 1 m within the inner rows (4th and 5th rows). Plants were harvested by cutting at the ground level and weighed. The plants were then separated into ears (cob + grains) and stovers (stem + leaves).

#### *Mean number of cobs per plant*

This was obtained by dividing the total number of cobs by the number of plants in the harvested area.

#### *Mean cob length*

The length of five dehusked maize cobs per plot was taken with a tape measure and the mean value determined.

#### *Mean cob diameter*

This was calculated from the cob girth which was obtained from measuring the circumference of five cobs per plot with the use of a tape measure and the values recorded, averaged and converted with a formula $d = C/\pi$ to obtain the diameter where C is the circumference and d is the diameter.

***Mean number of kernel rows per cob***

The number of rows per cob for five cobs from each plot was counted and the mean number determined.

***Mean number of kernels per row***

This was the number of grains counted in a row (for five cobs) and the mean number determined.

***Mean number of kernels per cob***

The total number of grains on five cobs from each plot was counted after they had been dried and shelled and was divided by the number of cobs to determine the mean number of kernels per cob.

***1000 grain weight***

One thousand grains were counted from each plot and weighed.

***Grain yields***

Grain yields were also estimated from grains from the shelled cobs from the harvested area on each plot at grain moisture content of 14% using a grain moisture meter (John Deere Moisture Chek Plus, Deere and company, USA) and weights recorded. Grain yield is the weight of the grain expressed in kilogram per hectare (kg ha$^{-1}$).

***Stover yields***

Stover yields were estimated from the stem and leaves of the harvested plants. After harvesting, the stem and leaves were sun dried until they attained a constant weight after which dry stover weights were recorded as stover yield in kg ha$^{-1}$. All weights were recorded using an electronic scale (Electronic Portable scale, Constant Company, China).

### 4.3.4. Data Analysis

The data collected from the field were subjected to analysis of variance (ANOVA) to establish single and interactive effects on maize phenology, growth and yield. The ANOVA was performed separately for each AEZ for the major season. Data were later combined across the AEZs and analysed for measured parameters. Treatment means were separated using Tukey's honest significance test at 5% level of probability. The standard error of the difference (SED) was used for the error bars in the graphs.

Statistical analyses were performed using the GenStat statistical package 12th edition (GenStat, 2009). Line graphs were constructed using Microsoft Excel Office 2010.

## 4.4. Results

### 4.4.1. Soil physical and chemical properties of the experimental site

The soils in the CSZ were loamy sand in texture whiles that of the SDFZ was sandy loam (Table 4.4). The results also showed that soils at the sites were generally low in fertility, acidic, with low amounts of the major nutrients such as N, P, K, Ca as well as organic matter which were all below average for optimal maize production (Table 4.4). The pH of the soils of the experimental sites was higher in the CSZ (6.62-6.64) than the SDFZ (5.91-6.18). Generally, soils in the SDFZ had relatively higher levels of soil nutrients than the CSZ.

**Table 4.4: Soil chemical and physical properties of experimental sites at 0 - 15 cm and 15 - 30 cm soil depths for 2017**

| | Agro-ecological zone | | | |
|---|---|---|---|---|
| | Coastal savannah | | Semi - deciduous forest | |
| Soil properties | 0-15 cm | 15-30 cm | 0-15 cm | 15-30 cm |
| **Chemical properties** | | | | |
| pH ($H_2O$) (1:2.5) | 6.64 | 6.62 | 6.18 | 5.19 |
| Total N (%) | 0.07 | 0.04 | 0.10 | 0.07 |
| Av. P (mg/kg) | 19.76 | 15.81 | 21.39 | 19.45 |
| Av. K (mg/kg) | 21.77 | 13.95 | 27.91 | 23.15 |
| Organic M (%) | 1.35 | 0.85 | 2.06 | 1.48 |
| Ex Ca ($cmol_c$ $kg^{-1}$) | 3.73 | 3.27 | 4.40 | 3.80 |
| Ex Mg ($cmol_c$ $kg^{-1}$) | 1.87 | 2.33 | 2.13 | 2.47 |
| Ex K ($cmol_c$ $kg^{-1}$ ) | 0.19 | 0.15 | 0.19 | 0.20 |
| Ex Na ($cmol_c$ $kg^{-1}$) | 0.51 | 0.46 | 0.45 | 0.55 |
| Ex. Acidity (cmol(+)$kg^{-1}$ | 0.13 | 0.15 | 0.12 | 0.14 |
| ECEC ($Al^{3+}$ + $H^+$).($cmol_c$ (+) $kg^{-1}$) | 6.43 | 6.36 | 7.29 | 7.16 |
| Base saturation (%) | 97.98 | 97.64 | 98.35 | 98.04 |
| **Physical characteristics** | | | | |
| Sand% | 78.67 | | 76.33 | |
| Silt% | 16.00 | | 17.00 | |
| Clay% | 5.33 | | 6.67 | |
| Textural class | Loamy sand | | Sandy loam | |

Source: Field data, Marfo-Ahenkora (2017)

### 4.4.2. Chemical properties of goat manure used for the study

The goat manure contains adequate amount of the major plant nutrients (N P K) for maize production (Table 4.5). The goat manure applied at 5 t $ha^{-1}$ had a nutrient content of 93.5 kg N $ha^{-1}$, 75.5 kg P $ha^{-1}$ and 31 kg K $ha^{-1}$.

**Table 4.5: Chemical properties of goat manure used for the study**

| Parameter | Composition/Amount |
|---|---|
| pH in ($H_2O$) (1: 2.5) | 8.4 |
| Organic carbon % | 22.5 |
| Total nitrogen (% N) | 1.87 |
| Total phosphorus (P %) | 1.51 |
| Total potassium (K %) | 0.62 |
| Total magnesium (Mg %) | 0.53 |
| C: N ratio | 12.03 |
| Iron (Fe %) | 0.68 |
| Zinc (Zn %) | 0.0013 |
| Copper (Cu %) | 0.0068 |
| Manganese (Mn %) | 0.0301 |
| Sodium (Na %) | 0.0003 |

Source: Field data, Marfo-Ahenkora (2017)

### 4.4.3. Rainfall amount at experimental sites during the experimental period

During the experimental period, rainfall (mm) was measured at the experimental site using a conventional rain gauge and the results have shown in Figure 4.2. Rainfall figures were means from the three communities in each zone. The amount of rainfall recorded from March 2017 to December 2017 varied for the different months of the year. During the year, rainfall peaked in May for the major season in the SDFZ but peaked in June in the CSZ. In the minor season, the rains peaked in October for both the SDFZ and the CSZ. Total rainfall of 716.7 mm and 601.3 mm was received from planting to physiological maturity (April to July) in the SDFZ and CSZ respectively in the major season.

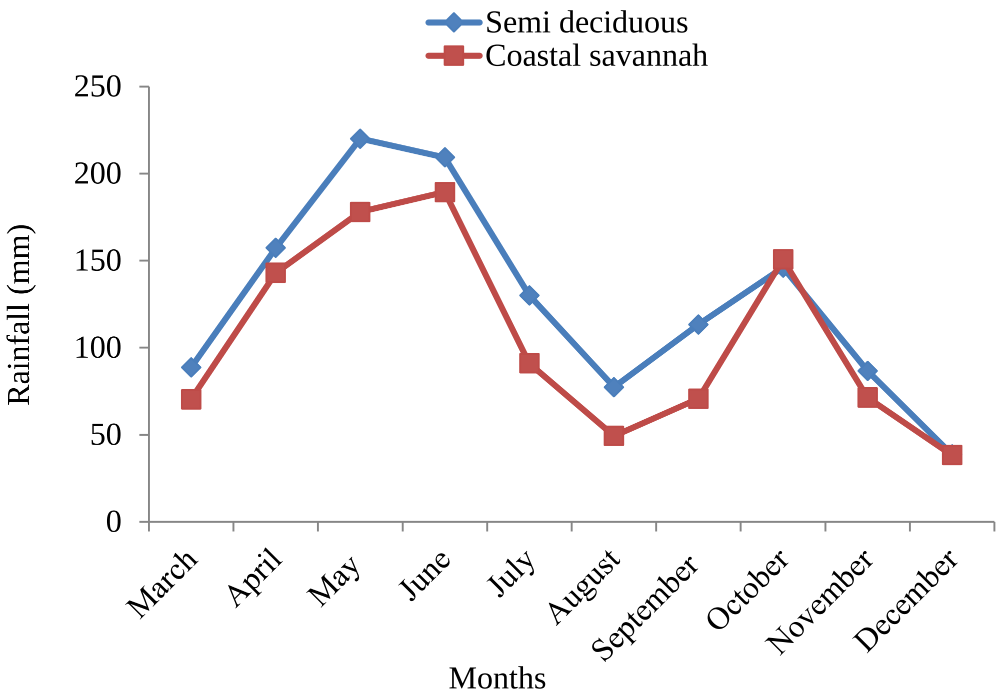


**Figure 4.2: Rainfall amount (mm) and distribution at the experimental sites**

**Table 4.6: Mean monthly minimum and maximum temperatures in the study areas.**

| Month | Minimum Temperature | | Maximum Temperature | |
|---|---|---|---|---|
| | SDFZ | CSZ | SDFZ | CSZ |
| March | 22.9 | 22.9 | 34.6 | 34.7 |
| April | 22.6 | 22.5 | 34.5 | 34.4 |
| May | 22.2 | 22.6 | 33.4 | 33.5 |
| June | 21.6 | 22.2 | 31.2 | 31.3 |
| July | 21.1 | 21.7 | 31.5 | 31.5 |
| August | 20.3 | 20.5 | 31.2 | 31.1 |
| September | 22 | 22.8 | 31.8 | 31.7 |
| October | 22.4 | 22.9 | 33.4 | 33.4 |
| November | 22 | 22.6 | 34.6 | 34.5 |
| December | 22 | 22.1 | 34.4 | 34.3 |

Source: Ghana Meteorological Agency

### 4.4.4. Phenology of three maize varieties under different soil amendments in the SDFZ and CSZ.

Results of phenological features such as anthesis, silking, anthesis–silking interval and physiological maturity of three maize varieties under different soil amendments have been presented in Tables 4.7.

**Table 4.7: Phenology of three maize varieties on four soil amendments in the Coastal savannah (CSZ) and Semi-deciduous forest zone (SDFZ).**

| Treatments | No of days to 50% Anthesis | | No of days to 50% silking | | Anthesis-Silking interval (ASI) | | Days to physiological maturity | |
|---|---|---|---|---|---|---|---|---|
| **Varieties** | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ |
| Ahomatea | 54.6 | 54.2 | 59.9 | 59.3 | 5.3 | 5.0 | 120.5 | 120.3 |
| Obatanpa | 53.6 | 52.6 | 58.6 | 57.2 | 5.0 | 4.6 | 105.2 | 104.2 |
| Omankwa | 41.2 | 41.4 | 44.2 | 43.9 | 3.0 | 2.5 | 90.6 | 89.7 |
| P-value | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 | <.001 |
| Tukey (5%) | 1.26 | 1.26 | 1.25 | 1.25 | 0.78 | 0.78 | 2.89 | 2.89 |
| **Soil amendments** | | | | | | | | |
| Fertilizer | 48.5 | 48.6 | 52.9 | 52.2 | 4.3 | 3.5 | 104.2 | 103.5 |
| Fert +manure | 48.7 | 48.6 | 52.5 | 52.1 | 3.8 | 3.4 | 104.2 | 103.9 |
| Manure | 49.9 | 49.4 | 54.8 | 53.9 | 4.8 | 4.4 | 106.5 | 105.4 |
| Control | 52.0 | 50.8 | 56.8 | 55.7 | 4.8 | 4.8 | 106.8 | 106.2 |
| P-value | <.001 | <.001 | <.001 | <.001 | 0.007 | 0.007 | 0.144 | 0.144 |
| Tukey (5%) | 1.60 | 1.60 | 1.59 | 1.59 | 0.98 | 0.98 | - | - |

Source: Field data, Marfo-Ahenkora (2018)

***Mean number of days to 50% anthesis***

The number of days to 50% anthesis varied for the three maize varieties and also for the soil amendments in both AEZs. The variety × soil amendment interaction was not significant (P = 0.90) as well as the location × variety interaction (P = 0.52) and location × soil amendment interaction (P = 0.74). There were however significant (P <0.001) differences among the varieties for 50% anthesis. Omankwa had significantly (P <0.001) fewer days (41.2 days in CSZ and 41.4 in SDFZ days) to 50% anthesis compared to Obatanpa and Ahomatea in both AEZs. Ahomatea had the most number of days (54.6 days in the CSZ and 54.2 days in the SDFZ) to 50% anthesis but was not significantly different from Obatanpa (Table 4.7).

The different soil amendments significantly (P <0.001) influenced the mean number of days to 50% anthesis in both AEZs. Plants on the control plots had significantly (P <0.001) more number of days to 50% anthesis than the rest of the soil amended treatments in both AEZs. There were no significant differences for number of days to 50% anthesis among plants on the sole fertilizer, fertilizer + manure and sole manure treatments in both AEZs. Even though plants on the sole fertilizer and fertilizer + manure treatments had less number of days to 50% anthesis than plants on the manure plots.

***Mean number of days to 50% silking***

The variety × soil amendment interaction was not significant (P = 0.64) as well as the location × variety interaction (P = 0.60) and location × soil amendment interaction (P = 0.95) for days to 50% silking. There were however significant differences (P<0.001) among the varieties for 50% silking. Omankwa had significantly (P<0.001) fewer number of days (44.2 days in the CSZ and 43.9 days in the SDFZ) to 50% silking compared to Obatanpa and Ahomatea. Ahomatea had the highest number of days (59.9 days in the CSZ and 59.3 days in the SDFZ) to 50% silking and was significantly different from Obatanpa in the SDFZ but not in the CSZ.

Application of soil amendments significantly (P <0.001) influenced mean number of days to 50% silking. Plants on the sole fertilizer and fertilizer + manure plots were not significantly different from each other for days to 50% silking but were significantly (P <0.001) less than that of plants on the control plots and the sole manure plots in both AEZs. Application of inorganic fertilizer either in combination with manure or as sole fertilizer significantly (P <0.001) decreased the number of days to silking and therefore hastened days to silking by about two to four days compared to plants on the manure and control plots (Table 4.7).

***Anthesis-Silking Interval (ASI)***

The variety × soil amendment interaction was not significant (P = 0.97) as well as the location × variety interaction (P = 0.91) and location × soil amendment interaction (P = 0.68) for ASI. Significant (P <0.001) differences were however observed among the maize varieties for ASI with Omankwa having the shortest intervals for ASI (3 days in the CSZ and 2.5 days in the SDFZ) which was significantly (P <0.001) different from Obatanpa and Ahomatea. Although Ahomatea had the longest interval for ASI (5.3 days in the CSZ) there was no significant (P <0.001) difference between Ahomatea and Obatanpa in both AEZs.

With regards to soil amendments for ASI, there was no significant difference between ASI of plants on sole manure plots and those on control plots in both AEZs but the two were significantly (P <0.007) different from ASI of plants on fert+ manure and sole fertilizer in the SDFZ and plants on fert+manure in the CSZ (Table 4.7).

***Mean number of days to physiological maturity***

The variety × soil amendment interaction was not significant (P = 1.00) as well as the location × variety interaction (P = 0.94), location × soil amendment interaction (P = 0.99) and soil amendment (P =0.144) for days to physiological maturity. Among the varieties, Ahomatea took significantly (P < 0.001) more days (120.5 days in the CSZ and 120.3 days in the SDFZ) to attain physiological maturity whiles Omankwa took significantly fewer number of days (90.6 days in the CSZ and 89.7 days in the SDFZ) to attain physiological maturity. Days to physiological maturity was not significantly influenced by soil amendments (Table 4.7).

### 4.4.5. Growth parameters of three maize varieties on four soil amendments in the SDFZ and CSZ

The growth parameters (plant height, stem girth and leaf area of three maize varieties under four soil amendments recorded at 5, 7, 9 and 11 weeks after sowing (WAS) in the SDFZ and the CSZ have been presented in Figures 4.3- 4.11.

***Mean plant height***

Mean plant heights recorded for Ahomatea, Obatanpa and Omankwa in the SDFZ and CSZ are shown in Figures 4.3-4.5. There were significant differences for variety at 5 WAS (P < 0.001), 7 WAS (P < 0.003), 9 WAS (P < 0.001) and 11 WAS (P < 0.001) for mean plant height in both AEZs. Soil amendments showed significant differences for plant height at 5 WAS (P < 0.001), 7 WAS (P < 0.001), 9 WAS (P < 0.001) and 11 WAS (P < 0.001) in both AEZs.

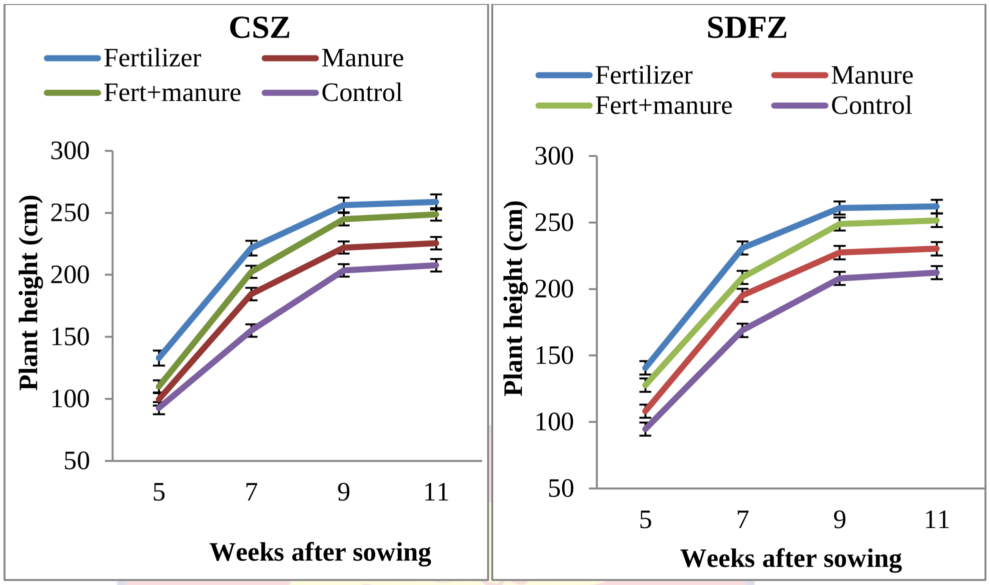


**Figure 4.3: Mean plant height (cm) of Ahomatea on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments.*

Plants on sole fertilizer plots for Ahomatea was significantly ($P < 0.001$) taller than the rest of the soil amendments for all the weeks after sowing and in both CSZ and SDFZ. Among the soil amendments, the plants on the control plots had the shortest plant height which was significantly ($P < 0.001$) different from plant heights of the rest of the soil amendments for all the weeks after sowing and in both AEZs for Ahomatea. The trend for plant height for the soil amendments were in the decreasing order of sole fertilizer > fertilizer + manure > sole manure > control in both AEZs.

The growth trend for plant height of Ahomatea showed that there was a rapid growth from 5 to 7 WAS for all the soil amendments, then a steady growth from 7 to 9 WAS and then very marginal height gains were recorded between 9 and 11 WAS for both the CSZ and SDFZ (Figure 4.3).

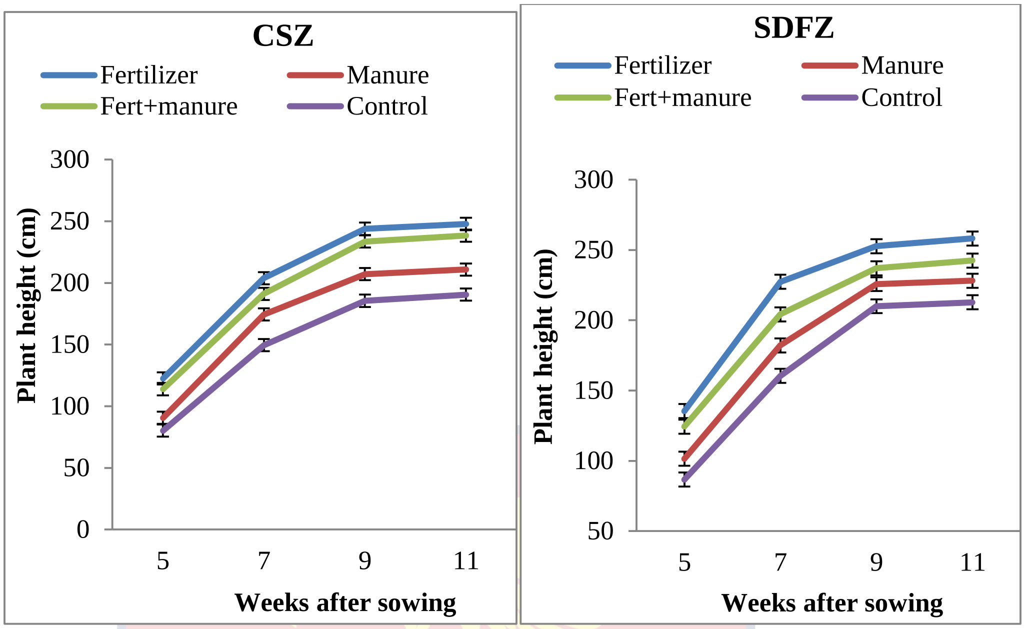


**Figure 4.4: Mean plant height (cm) of Obatanpa on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments.*

Plants on sole fertilizer plots for Obatanpa was significantly ($P < 0.001$) taller than the rest of the soil amendments for all the weeks after sowing and in both CSZ and SDFZ. Obatanpa on the control plots had significantly shorter ($P < 0.001$) plant height among the soil amendments for all the weeks after sowing and in the CSZ and SDFZ. The trend for plant height of the soil amendments for Obatanpa were in the order of sole fertilizer > fertilizer + manure > sole manure > control in both AEZs. The growth trend for plant height of Obatanpa showed that there was a rapid growth from 5 to 7 WAS for all the soil amendments, then a steady growth from 7 to 9 WAS and then very marginal height gains were recorded between 9 and 11 WAS for both the CSZ and SDFZ (Figure 4.4).

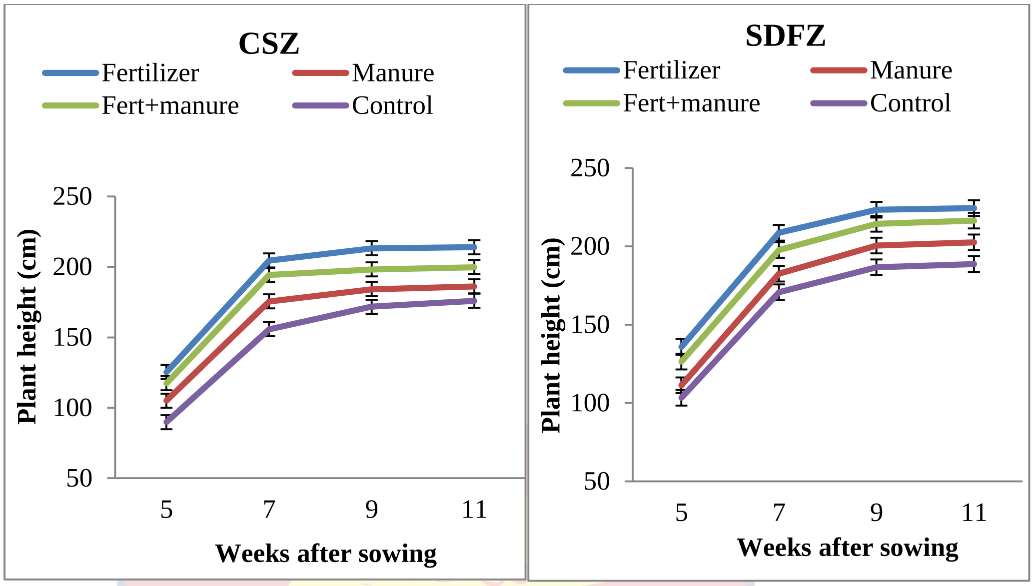


**Figure 4.5: Mean plant height (cm) of Omankwa on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments.*

Plants on sole fertilizer plots for Omankwa was significantly ($P < 0.001$) taller than the rest of the soil amendments for all the weeks after sowing and in both CSZ and SDFZ. Omankwa variety on the control plots had significantly shorter ($P < 0.001$) plant height among the soil amendment treatments for all the weeks after sowing and in both the CSZ and SDFZ. The trend for plant height of the soil amendments were followed this trend: sole fertilizer > fertilizer + manure > sole manure > control in both AEZs.

The growth trend for plant height of Omankwa showed that there was a rapid growth from 5 to 7 WAS for all the soil amendments, then a steady growth from 7 to 9 WAS and then very negligible height gains were recorded between 9 and 11 WAS for both the CSZ and SDFZ (Figure 4.5). Generally, plants from the SDFZ had significantly ($P < 0.001$) taller plant heights than that of the CSZ for all the varieties.

### Mean stem girth

Mean stem girth recorded at 5, 7, 9 and 11 WAS in the SDFZ and CSZ are outlined in Figures 4.6-4.8. Significant (P < 0.001) differences were observed for maize variety and also soil amendments for all the weeks after sowing in both AEZs.

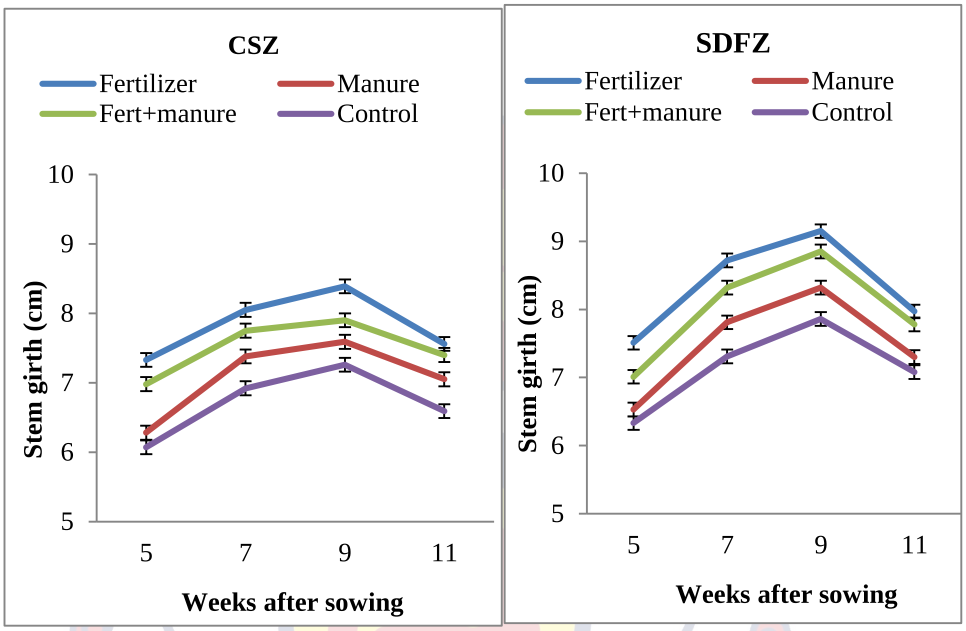


**Figure 4.6: Mean stem girth (cm) of Ahomatea on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments*

Stem girth of Ahomatea on sole fertilizer plots was significantly (P < 0.001) bigger than the rest of the soil amendments in all the weeks after sowing except at 11 WAS when plants on the sole fertilizer and fert +manure treatments were not significantly different in both AEZs. Ahomatea on the control plots had the smallest stem girth compared to the other soil amendments in both AEZ over the period.

The trend of the soil amendments were in the decreasing order of sole fertilizer > fertilizer + manure > sole manure > control for stem girth in both AEZs. The growth trend for stem girth of Ahomatea showed that there was a quick growth from 5 to 7 WAS for all the soil amendments, then a steady growth from 7 to 9

WAS and then a decline between 9 and 11 WAS for both the CSZ and SDFZ (Figure 4.6).

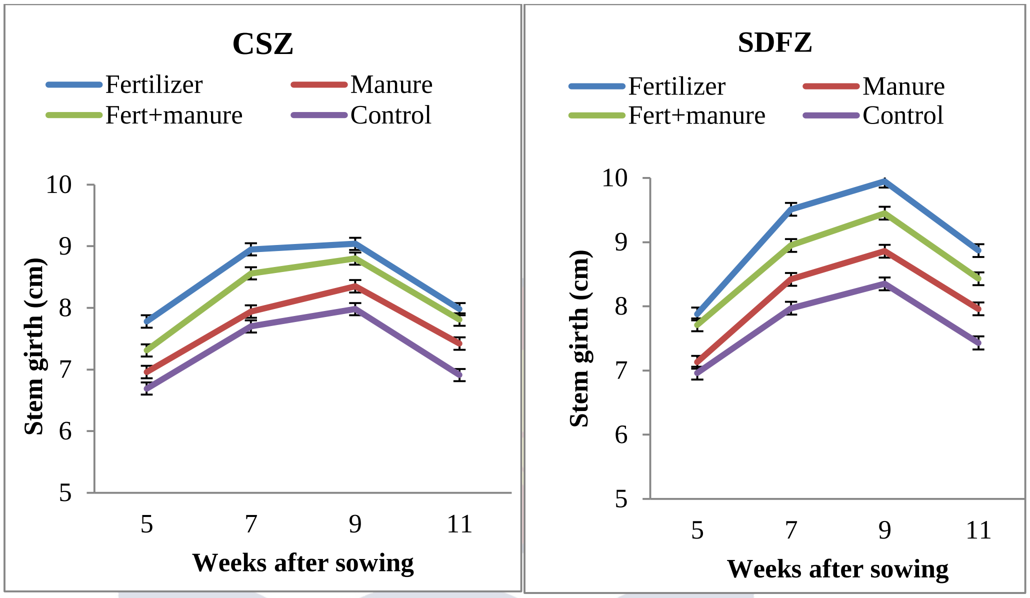


**Figure 4.7: Mean stem girth (cm) of Obatanpa on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments*

Plants on sole fertilizer plots for Obatanpa was significantly ($P < 0.001$) bigger than the rest of the soil amendments for all the weeks after sowing except at 5 WAS for SDFZ and 11 WAS in the CSZ where plants on sole fertilizer was not significantly different from plants on fert+ manure plots. Obatanpa variety on the control plots had significantly ($P < 0.001$) smaller stem girth among the soil amendments for all the weeks after sowing and in both AEZs except for 5 WAS in both the SDFZ and CSZ where plants on the control plot was not significantly different from plants on the manure plots.

The trend for stem girth of Obatanpa with regards to the soil amendments were in the order of sole fertilizer > fertilizer + manure > sole manure > control in both AEZs. The growth trend for stem girth of Obatanpa showed that there was a rapid growth from 5 to 7 WAS for all the soil amendments, then a steady growth from 7 to 9 WAS and then a decline between 9 and 11 WAS for both the CSZ and SDFZ.

Stem girth of Omankwa on sole fertilizer plots was significantly ($P < 0.001$) bigger than the rest of the soil amendments for all the weeks after sowing in the SDFZ. In the CSZ however, Omankwa on sole fertilizer had stem girth which was generally similar to that of plants on fert+ manure treatments over the period. Omankwa on the control plots had smaller stem girth than the rest of the soil amendments for all the weeks after sowing and in both the CSZ and SDFZ.

The trend for stem girth of Omankwa with regards to the soil amendments were in the order of sole fertilizer > fertilizer + manure > sole manure > control in both AEZs. The growth trend for stem girth of Omankwa showed that there was a rapid growth from 5 to 7 WAS for all the soil amendments, and then a steady decline from 7 to 11 WAS for both the CSZ and SDFZ (Figure 4.8).

Among the varieties, Obatanpa had the biggest stem girth and was significantly different ($P < 0.001$) from Ahomatea and Omankwa varieties from 5 to 11 WAS in both the SDFZ and CSZ. Generally, plants from the SDFZ had significantly ($P < 0.001$) taller plant heights, bigger stem girths and larger leaf area than that of the CSZ for all the varieties.

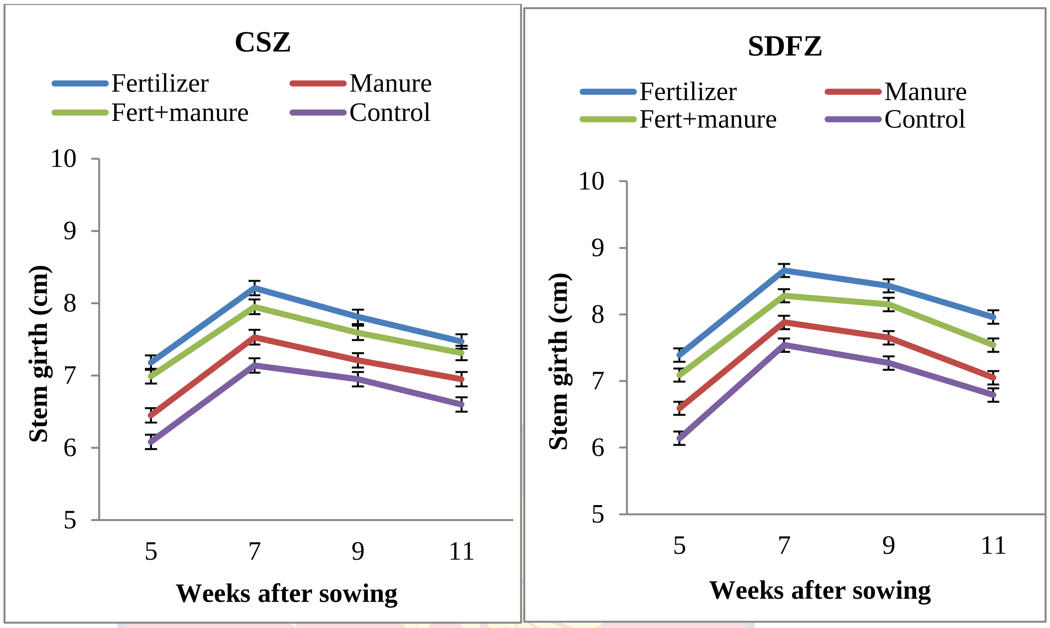


**Figure 4.8: Mean stem girth (cm) of Omankwa on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments.*

### Mean leaf area

The results for leaf area recorded at 5, 7, 9 and 11 WAS in the SDFZ and CSZ for the three varieties have been presented in Figure 4.9-4.11.There were significant differences for variety at 5 WAS (P = 0.002), 7 W (AS (P < 0.001), 9 WAS (P < 0.001) and 11 WAS (P < 0.001) for leaf area in both AEZs.

With regards to soil amendments, there were significant differences for leaf area at 5 WAS (P < 0.001), 7 WAS (P < 0.001), 9 WAS (P < 0.001) and 11 WAS (P < 0.001) in both AEZs.

Leaf area for Ahomatea on sole fertilizer plots was significantly (P < 0.001) larger than the rest of the soil amendments for all the weeks after sowing except in the 11th week where no significant difference was observed between sole fertilizer and fert+ manure in the SDFZ. Plants on the control plots had significantly (P < 0.001) smaller leaf area from 5 to 11 WAS than the rest of the soil amendments in both AEZs except in the CSZ where no significant difference was observed between leaf area on control plots and sole manure and again between leaf area of sole manure and the fert + manure plots at 5 WAS (Figure 4.9).

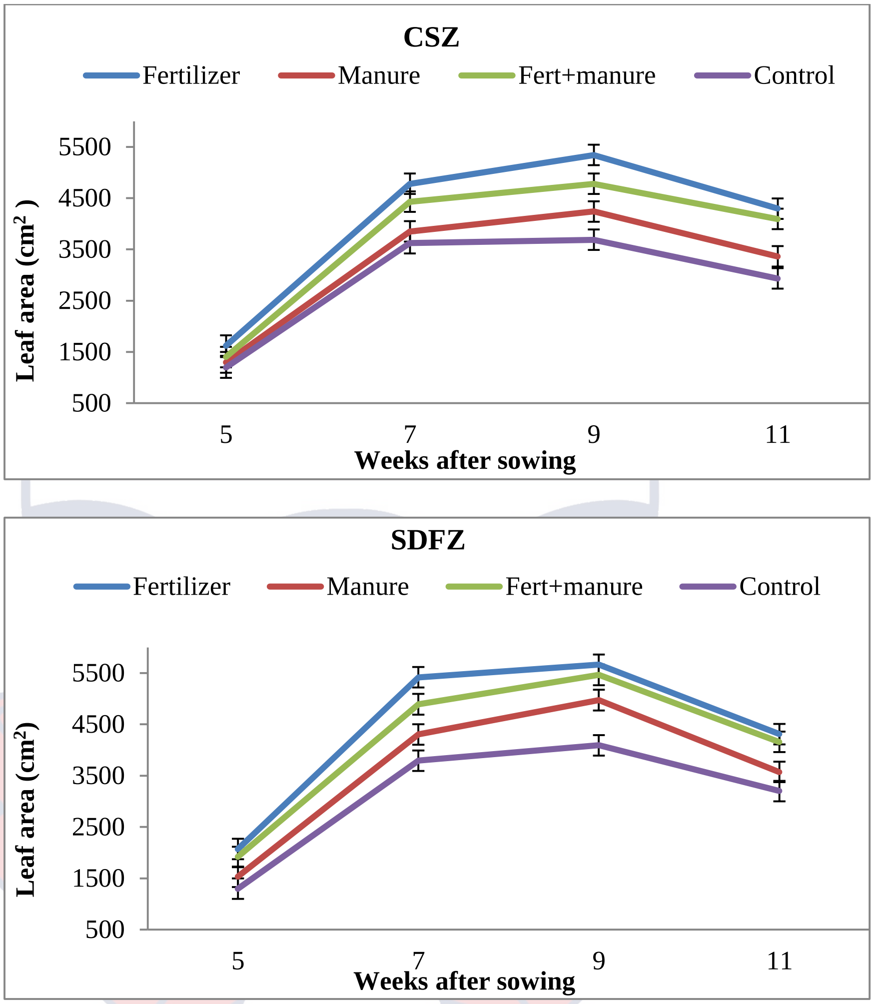


**Figure 4.9: Mean leaf area ($cm^2$) of Ahomatea on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments.*

The trend for the soil amendments were in the decreasing order of sole fertilizer > fertilizer + manure > sole manure > control for leaf area in both the CSZ and SDFZ. The growth pattern for leaf area of Ahomatea showed that generally leaf area increased sharply from 5 to 7 WAS for all the soil amendments, then a steady increase from 7 to 9 WAS and a decline from 9 to 11 WAS for both AEZs (Figure 4.9).

Obatanpa on sole fertilizer plots had leaf area which was significantly ($P < 0.001$) larger than the rest of the soil amendments for all the weeks after sowing in both AEZs. Plants on the control plots had significantly ($P < 0.001$) smaller leaf area from 5 to 11 WAS than the rest of the soil amendments in both AEZs except in the SDFZ where no significant difference was observed between leaf area on control plots and sole manure at 11 WAS.

The trend for the soil amendments were in the decreasing order of sole fertilizer > fertilizer + manure > sole manure > control for leaf area of Obatanpa in both CSZ and SDFZ. The growth pattern for leaf area of Obatanpa showed that, leaf area increased sharply from 5 to 7 WAS for all the soil amendments, then a steady increase from 7 to 9 WAS and a decline from 9 to 11 WAS for both AEZs (Figure 4.10).

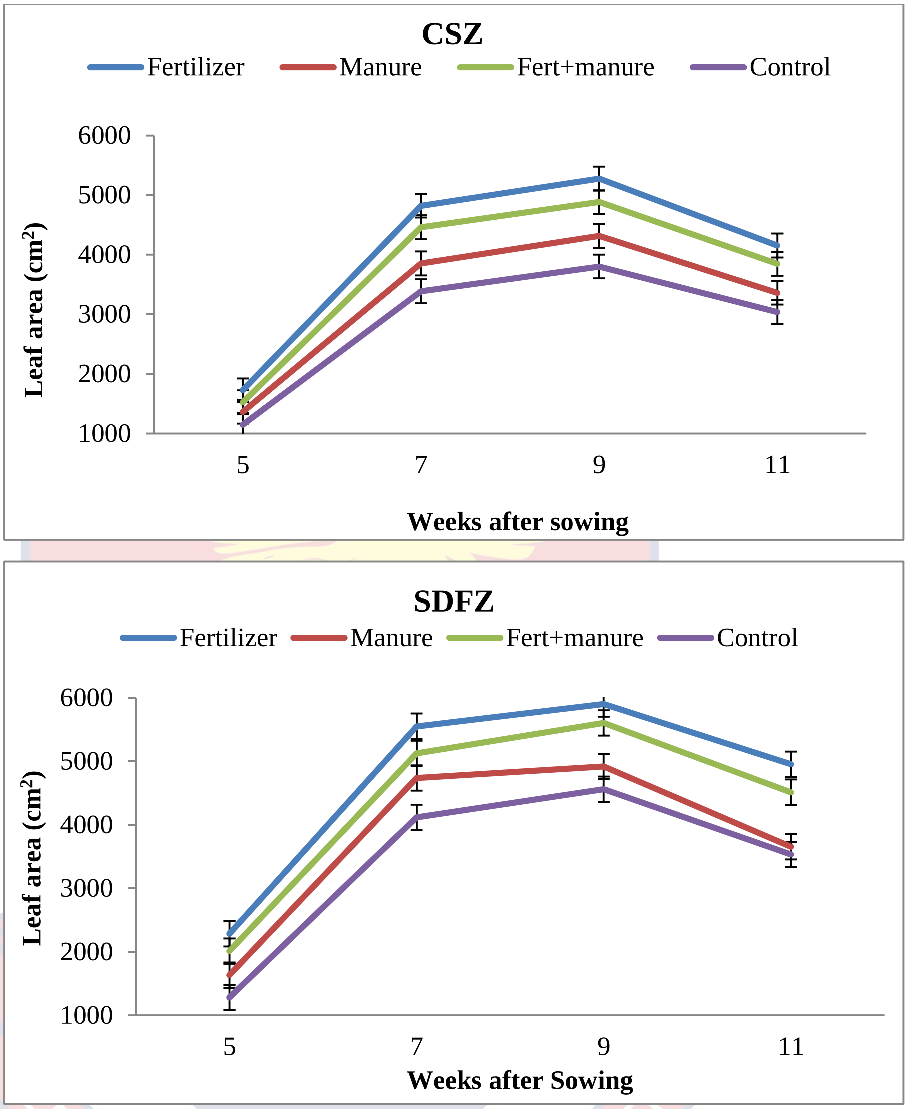


**Figure 4.10: Mean leaf area (cm$^2$) of Obatanpa on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments.*

Leaf area for Omankwa on sole fertilizer plots was significantly ($P < 0.001$) larger than the rest of the soil amendments for all the weeks after sowing. Plants on the control plots had significantly ($P < 0.001$) smaller leaf area than the rest of the soil amendments from 5 to 11 WAS in both AEZs except in the CSZ where no significant difference was observed for leaf area for plants on control plots and sole manure plots at 5 WAS. In both AEZs, the trend for soil amendments followed this trend: sole fertilizer > fertilizer + manure > sole manure > control for leaf area of Omankwa.

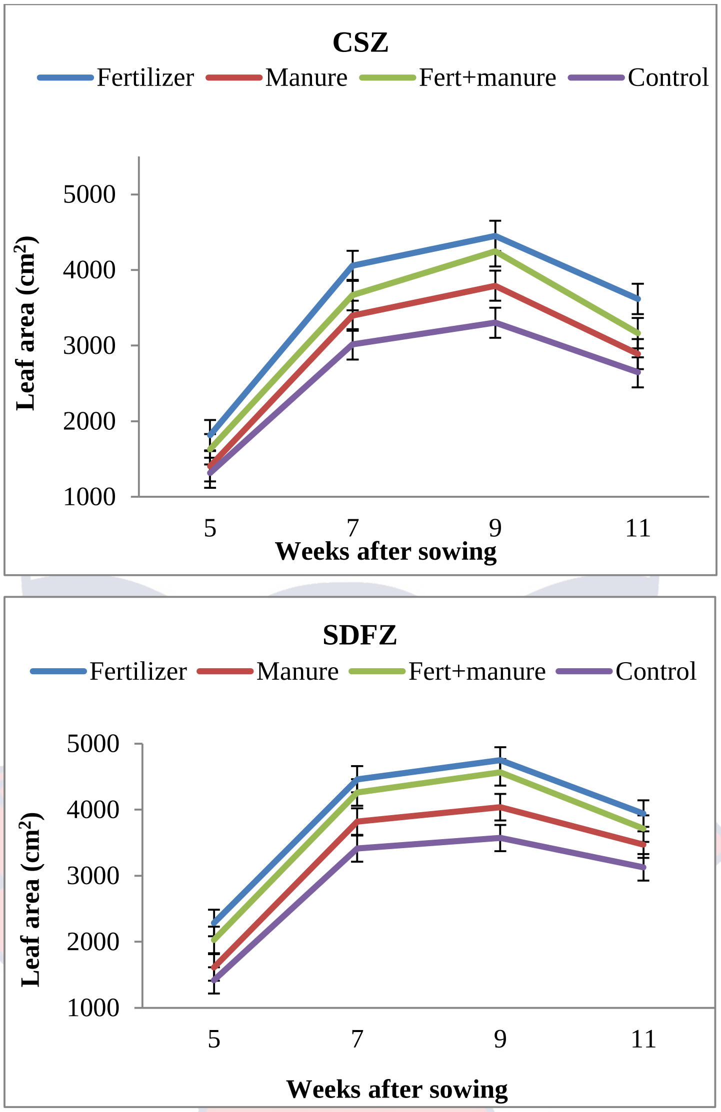


**Figure 4.11**: **Mean leaf area ($cm^2$) of Omankwa on different soil amendments in CSZ and SDFZ.** *Error bars represent the SED of soil amendments.*

The growth pattern for leaf area of Omankwa showed that, leaf area increased sharply from 5 to 7 WAS for all the soil amendments, then a gradual steady increase from 7 to 9 WAS and a decline from 9 to 11 WAS for both the CSZ and SDFZ

(Figure 4.11). For all the varieties, significantly ($P < 0.001$) bigger leaf area was observed in the SDFZ than in the CSZ.

### 4.4.5. Yield attributes of three maize varieties under different soil amendments in the SDFZ and CSZ.

Yield attributes of maize such as mean number of cobs per plant, number of kernels per cob, number of kernels per row, number of kernel rows per cob, cob weight, cob diameter, cob length and weight of 1000 grains are presented in Table 4.8 and 4.9.

Table 4.8 shows the yield attributes of the maize varieties under soil amendments in both the CSZ and SDFZ. The number of cobs per plant was significantly ($P <0.001$) influenced by the interaction between variety and soil amendment in both locations. Omankwa and Obatanpa with fertilizer or fertilizer + manure resulted in significantly ($P <0.001$) higher and similar number of cobs per plant than when only manure or no soil amendments (control) were applied on Omankwa and Obatanpa in both locations. The use of Ahomatea resulted in significantly ($P <0.001$) lower and similar number of cobs per plant irrespective of the soil amendment used or AEZ.

The number of kernel rows per cob, number of kernels per row and number of kernels per cob were significantly ($P <0.001$) influenced by variety and also soil amendment but not the interaction between variety and soil amendment in both locations. Omankwa and Obatanpa had significantly ($P <0.001$) higher and similar number of kernel rows per cob, number of kernels per cob and number of kernels per row than Ahomatea.

**Table 4.8 Yield attributes of three maize varieties under four soil amendments in the Coastal savannah (CSZ) and Semi-deciduous forest zone (SDFZ)**

| Treatments | No. of cobs per plant | | No. of kernel rows per cob | | No. of kernels per row | | No of kernels per cob | |
|---|---|---|---|---|---|---|---|---|
| **Varieties** | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ |
| Ahomatea (A) | 1.04 | 1.05 | 13.2 | 13.5 | 30.3 | 31.3 | 412.1 | 429.5 |
| Obatanpa (Obt) | 1.05 | 1.10 | 13.7 | 13.9 | 32.2 | 32.5 | 436.9 | 448.8 |
| Omankwa (Omk) | 1.07 | 1.17 | 14.0 | 14.7 | 33.4 | 33.7 | 454.2 | 463.1 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 0.027 | 0.027 | 0.49 | 0.49 | 1.11 | 1.11 | 21.06 | 21.06 |
| **Soil amendments** | | | | | | | | |
| Fertilizer (Fert) | 1.12 | 1.18 | 14.1 | 14.8 | 33.4 | 34.2 | 474.0 | 479.2 |
| Fert +man (F+M) | 1.08 | 1.16 | 13.9 | 14.3 | 32.6 | 33.6 | 442.9 | 467.5 |
| Manure (M) | 1.01 | 1.07 | 13.5 | 13.9 | 31.9 | 32.0 | 421.6 | 440.7 |
| Control (C) | 1.00 | 1.01 | 12.9 | 13.2 | 29.9 | 30.1 | 399.0 | 401.0 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 0.034 | 0.034 | 0.62 | 0.62 | 1.39 | 1.39 | 26.67 | 26.67 |
| **Interaction** | | | | | | | | |
| A×Fert | 1.07 | 1.09 | 13.7 | 14.2 | 32.1 | 33.5 | 464.7 | 471.8 |
| A× F+M | 1.06 | 1.08 | 13.6 | 13.6 | 31.1 | 32.7 | 429.8 | 459.9 |
| A× M | 1.00 | 1.02 | 13.0 | 13.3 | 30.4 | 30.3 | 389.6 | 422.0 |
| A×C | 1.00 | 1.00 | 12.3 | 12.8 | 27.4 | 28.5 | 364.1 | 364.2 |
| Obt × Fert | 1.14 | 1.17 | 14.2 | 14.3 | 33.5 | 34.0 | 470.6 | 476.7 |
| Obt × F+M | 1.08 | 1.18 | 13.8 | 14.1 | 32.0 | 33.3 | 436.6 | 465.8 |
| Obt × M | 1.00 | 1.04 | 13.6 | 14.0 | 32.0 | 32.2 | 426.8 | 435.9 |
| Obt × C | 1.00 | 1.02 | 13.1 | 13.4 | 31.2 | 30.5 | 413.7 | 416.7 |
| Omk × Fert | 1.14 | 1.29 | 14.5 | 15.8 | 34.7 | 35.0 | 486.8 | 489.2 |
| Omk × F+M | 1.09 | 1.24 | 14.4 | 15.3 | 34.8 | 34.9 | 462.4 | 476.8 |
| Omk × M | 1.03 | 1.13 | 14.0 | 14.5 | 33.2 | 33.5 | 448.3 | 464.2 |
| Omk × C | 1.01 | 1.02 | 13.3 | 13.4 | 31.0 | 31.4 | 419.3 | 422.1 |
| P-value | 0.016 | 0.016 | 0.867 | 0.867 | 0.662 | 0.662 | 0.508 | 0.508 |

Source: Field data, Marfo-Ahenkora (2018)

Also, the use of sole fertilizer and fertilizer + manure resulted in significantly (P <0.001) higher and similar number of kernel rows per cob, number of kernels per cob and number of kernels per row than the use of only manure and no amendments-control (Table 4.8).

**Table 4.9: Yield attributes (mean weight per cob, cob diameter, cob length, 1000 grain weight) of three maize varieties under four soil amendments in the CSZ and SDFZ**

| Treatments | Weight per cob (g) | | Cob diameter (cm) | | Cob length (cm) | | 1000 grain weight (g) | |
|---|---|---|---|---|---|---|---|---|
| **Varieties** | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ |
| Ahomatea (A) | 161.1 | 166.8 | 3.45 | 3.93 | 14.3 | 14.8 | 232.5 | 244.8 |
| Obatanpa (Obt) | 188.6 | 199.6 | 4.17 | 4.30 | 15.5 | 15.8 | 265.2 | 270.9 |
| Omankwa (Omk) | 205.0 | 220.0 | 4.10 | 4.23 | 15.4 | 15.7 | 269.6 | 276.8 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 13.39 | 13.39 | 0.105 | 0.105 | 0.53 | 0.53 | 3.67 | 3.67 |
| **Soil amendments** | | | | | | | | |
| Fertilizer (Fert) | 200.4 | 211.1 | 4.10 | 4.35 | 16.2 | 16.4 | 274.6 | 284.6 |
| Fert +man (F+M) | 198.3 | 208.6 | 4.09 | 4.23 | 15.9 | 16.1 | 269.9 | 280.8 |
| Manure (M) | 177.4 | 192.1 | 3.82 | 4.06 | 14.8 | 15.2 | 253.3 | 261.7 |
| Control (C) | 163.3 | 170.1 | 3.61 | 4.03 | 13.4 | 14.1 | 225.2 | 229.4 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 16.96 | 16.96 | 0.133 | 0.133 | 0.67 | 0.67 | 4.65 | 4.65 |
| **Interaction** | | | | | | | | |
| A×Fert | 181.3 | 188.1 | 3.63 | 4.13 | 15.8 | 16.0 | 251.3 | 264.6 |
| A× F+M | 181.1 | 186.0 | 3.62 | 4.12 | 15.4 | 15.5 | 243.0 | 260.9 |
| A× M | 146.3 | 157.2 | 3.37 | 3.79 | 13.5 | 14.2 | 225.1 | 239.0 |
| A×C | 135.5 | 135.9 | 3.19 | 3.67 | 12.4 | 13.6 | 210.7 | 214.6 |
| Obt × Fert | 203.9 | 214.3 | 4.37 | 4.53 | 16.5 | 16.9 | 285.0 | 291.6 |
| Obt × F+M | 200.3 | 209.1 | 4.35 | 4.33 | 16.4 | 16.4 | 279.6 | 289.9 |
| Obt × M | 184.0 | 192.2 | 4.14 | 4.23 | 15.4 | 15.4 | 266.3 | 272.0 |
| Obt × C | 166.1 | 182.9 | 3.81 | 4.12 | 13.8 | 14.4 | 230.0 | 230.0 |
| Omk × Fert | 215.9 | 231.0 | 4.32 | 4.39 | 16.2 | 16.3 | 287.7 | 297.7 |
| Omk × F+M | 213.5 | 230.8 | 4.30 | 4.24 | 1.61 | 16.2 | 287.0 | 291.6 |
| Omk × M | 202.0 | 227.0 | 3.96 | 4.18 | 15.4 | 15.9 | 268.6 | 274.3 |
| Omk × C | 188.4 | 191.3 | 3.83 | 4.10 | 13.8 | 14.4 | 235.0 | 243.6 |
| P-value | 0.704 | 0.704 | 0.892 | 0.892 | 0.432 | 0.432 | 0.001 | 0.001 |

Source: Field data, Marfo-Ahenkora (2018)

Yield characteristics such as mean cob length, cob diameter, cob weight and 1000 grain weight of three maize varieties under different soil amendments in both locations have been presented in Table 4.9. Mean cob length, cob diameter, cob weight and 1000 grain weight were significantly (P <0.001) influenced by variety and also soil amendment but not the interaction between variety and soil amendment.

Omankwa and Obatanpa recorded similar and significantly (P <0.001) higher cob length, diameter and weight than Ahomatea in both locations. Omankwa however had significantly (P <0.001) bigger cob weight than Obatanpa. The use of sole fertilizer or fertilizer + manure resulted in similar and significantly (P <0.001) higher average cob length, diameter and weight than the use of only manure and the control for both locations.

The weight of a thousand (1000) grain was significantly (P <0.001) influenced by variety and also soil amendment. The interaction of variety × soil amendment was also significant (P = 0.001) for 1000 grain weight. The 1000 grain weight of Omankwa and Obatanpa were significantly (P <0.001) heavier and similar when planted with fertilizer alone or with fertilizer + manure. Ahomatea had significantly (P <0.001) lighter grain weight than that of both Obatanpa and Omankwa irrespective of the soil amendments used. The use of sole fertilizer or fertilizer + manure again resulted in similar and significantly (P <0.001) higher 1000 grain weight than the use of only manure and control (no amendment) for both locations (Table 4.9).

### 4.4.6. Grain and stover yields of three maize varieties on four soil amendments in the SDFZ and CSZ

The general trend for grain yields and stover yields of three maize varieties on four soil amendments in the SDFZ and CSZ have been presented in Figure 4.12 & 4.13. Significant ($P < 0.001$) interactions between variety and soil amendment were observed on maize grain yield in both locations. The maize grain yields under the various soil amendments were similar for both locations (SDFZ and CSZ). The grain yield of Obatanpa and Omankwa followed a similar trend of sole fertilizer > fert + manure > manure > control. Although, the grain yield of Ahomatea followed a similar trend of fertilizer > fert + manure > manure > control, it was however significantly ($P < 0.001$) lower than Obatanpa and Omankwa in both locations. Thus, application of sole fertilizer or fert+ manure resulted in significantly ($P < 0.001$) higher and similar yield for Obatanpa and Omankwa than Ahomatea in both locations.

Among the varieties, Omankwa had the highest grain yields whilst Ahomatea which is a local variety had the lowest grain yield irrespective of the soil amendments in both AEZs. Plants on the control plots (no amendment) had significantly ($P < 0.001$) lower grain yields than the rest of the soil amendments. Generally, grain yields were significantly ($P < 0.001$) higher in the SDFZ than the CSZ (Figure 4.12).

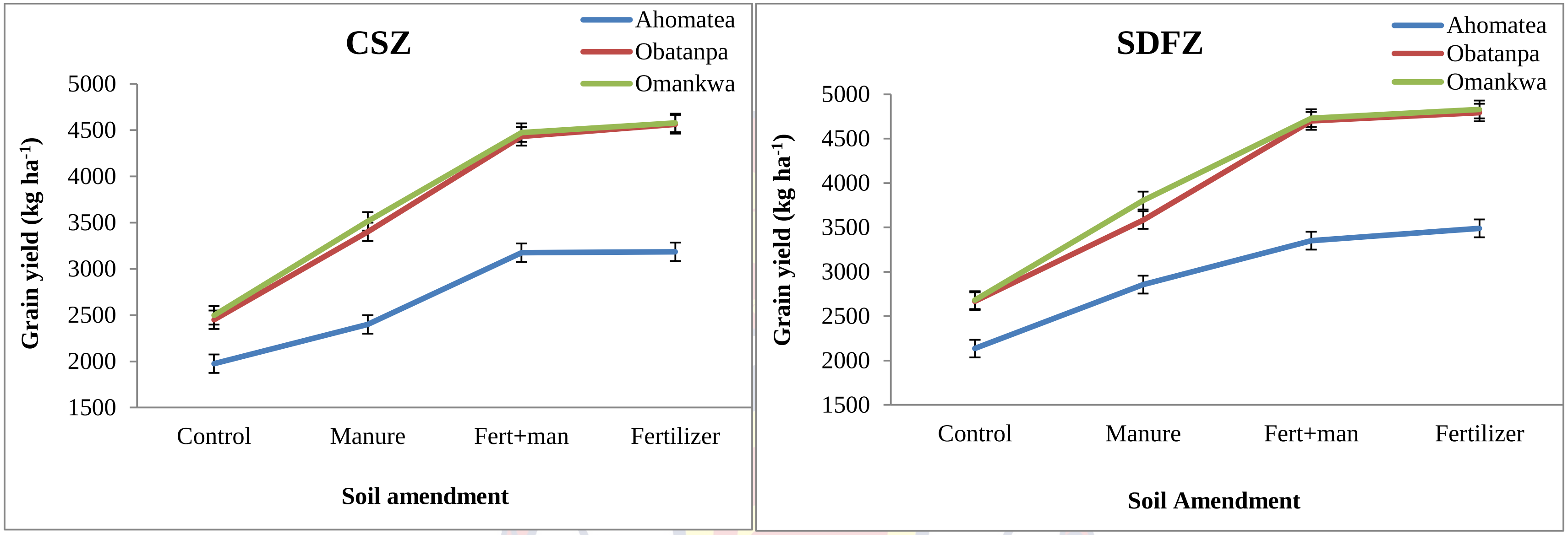


**Figure 4.12**: **Mean grain yield (kg ha$^{-1}$) of three maize varieties under different soil amendments in the Coastal Savannah (CSZ) and Semi deciduous forest zones (SDFZ). Fert – Fertilizer; Man – Manure.** *Error bars represent the SED of soil amendments.*

There were percentage increases in yield of maize on all the soil amendments over the control in both AEZs. In the SDFZ, Omankwa had yield increases of 80.1% on sole fertilizer plots, 76.5% on fertilizer + manure plots and 41.8%, on sole manure plots over the control plots. Obatanpa also had yield increases of 79.7% on sole fertilizer plots, 76.1%, on fertilizer + manure plots and 34.3% on sole manure plots over the control plots. Ahomatea (local variety) also had yield increases of 63.4%, 56.9%, and 33.8% over plants in the control plots for sole fertilizer, fertilizer + manure, and sole manure plots respectively in the SDFZ.

In the CSZ, Omankwa had percentage yield increases of 83.3%, 79.1%, and 40.7%, for plants on sole fertilizer, fertilizer + manure, and sole manure respectively over the plants on the control plots. Obatanpa also had yield increases of 86.2%, 80.8% and 38.7% for plants on sole fertilizer, fertilizer + manure and sole manure respectively over the plants on the control plots. The yield increases for Ahomatea (local variety) was 61.2%, 60.8%, and 21.5% for plants on sole fertilizer, fertilizer + manure and sole manure plots respectively over the control plots (Table 4.10).

Generally, plants on the sole fertilizer treated plants had the highest percentage increase in yields over plants on the control plots for all the varieties while plants on the sole manure plots recorded the lowest percentage increase over the control plots in both AEZs.

**Table 4.10: Mean grain yield of maize under different soil amendments and percentage yield increase over plants in control plot in the SDFZ and CSZ.**

| Treatments | Grain yield (kg ha$^{-1}$) | | Increase in yield over control plot (%) | |
|---|---|---|---|---|
| | SDFZ | CSZ | SDFZ | CSZ |
| Omankwa - sole fertilizer | 4828.3 | 4578.0 | 80.1 | 83.3 |
| Omankwa - fertilizer +manure | 4731.3 | 4474.0 | 76.5 | 79.1 |
| Omankwa - sole manure | 3802.3 | 3514.0 | 41.8 | 40.7 |
| Omankwa - control | 2681.0 | 2498.0 | - | - |
| Obatanpa - sole fertilizer | 4794.0 | 4564.0 | 79.7 | 86.2 |
| Obatanpa - fertilizer + manure | 4700.0 | 4431.7 | 76.1 | 80.8 |
| Obatanpa - sole manure | 3583.0 | 3399.0 | 34.3 | 38.7 |
| Obatanpa - control | 2668.3 | 2451.0 | - | - |
| Ahomatea - sole fertilizer | 3489.7 | 3184.3 | 63.4 | 61.2 |
| Ahomatea - fertilizer +manure | 3350.7 | 3175.7 | 56.9 | 60.8 |
| Ahomatea - sole manure | 2856.7 | 2400.0 | 33.8 | 21.5 |
| Ahomatea- control | 2135.1 | 1975.3 | - | - |

Source: Field data, Marfo-Ahenkora (2018)

Omankwa out yielded the local variety by 35.6% in the SDFZ and 40.3% in the CSZ whiles Obatanpa also out yielded the local variety by 33.1% in the SDFZ and 38.3% in the CSZ. The general observation was that Omankwa had slightly higher percentage yield increases over the local variety than Obatanpa in both AEZs (Table 4.11).

**Table 4.11: Mean grain yield and percentage yield increase of Omankwa and Obatanpa over the local variety in the SDFZ and CSZ in the major season of 2017.**

| Variety | Grain yields (kg ha$^{-1}$) | | Increase in yield over local variety (%) | |
|---|---|---|---|---|
| | SDFZ | CSZ | SDFZ | CSZ |
| Omankwa | 4010.8 | 3766.0 | 35.6 | 40.3 |
| Obatanpa | 3936.3 | 3711.4 | 33.1 | 38.3 |
| Local variety | 2958.0 | 2683.8 | - | - |

Source: Field data, Marfo-Ahenkora (2018)

The stover yields of three maize varieties under four soil amendments have been presented in Figure 4.13. The agro-ecological zones and soil amendment interacted significantly ($P < 0.001$) for stover yields of the maize. The stover yield of the three varieties followed similar trend of fertilizer > fert+manure > manure > control in both locations. However, sowing the three maize varieties under fertilizer alone or fertilizer + manure resulted in significantly ($P < 0.001$) higher and similar stover yields in SDFZ than in the CSZ. Generally, Ahomatea and Obatanpa produced more stover yield than Omankwa in both locations although Obatanpa had the highest stover yields among all the varieties for all the soil amendments. Stover yields on the control plots (no amendment) were significantly ($P < 0.001$) lower than yields on the rest of the soil amendments (Figure 4.13).

Generally, the results showed that grain and stover yields were influenced significantly ($P < 0.001$) by the application of manure and /or inorganic fertilizers in all the AEZs with plants on the sole fertilizer treated plots producing higher grain and stover yields compared to the combined treatments (fertilizer + manure) for all varieties in the major season. It was observed that grain yield and stover yields were significantly higher ($P < 0.001$) at the SDFZ than the CSZ.

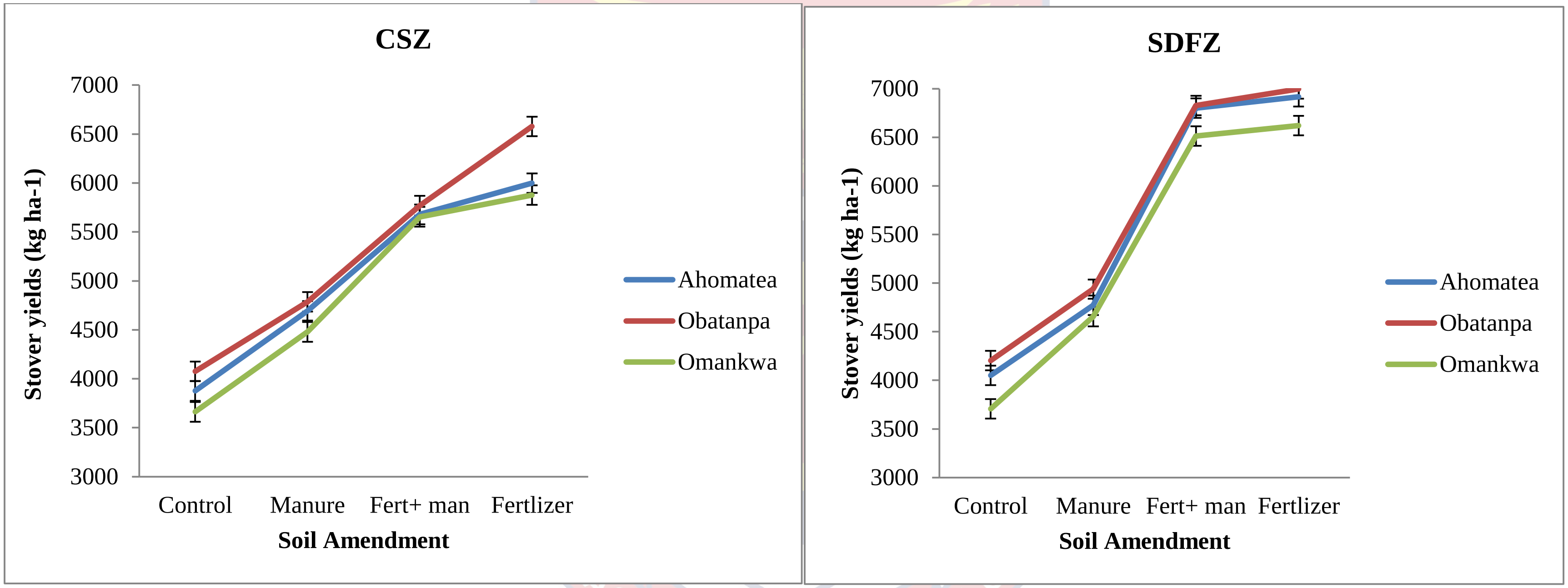


**Figure 4:13: Mean stover yield (kg ha$^{-1}$) of three maize varieties under different soil amendments in the Coastal Savannah (CSZ) and Semi deciduous forest zones (SDFZ). Fert – Fertilizer; Man – Manure.** *Error bars represent the SED of soil amendments.*

## 4.5. Discussion

### 4.5.1. Phenology, growth and yield performance of three maize varieties in two agro-ecological zones

*Phenology*

Crop characteristics such as variety have been reported to influence the duration of maize phenological development (Kisaka, 2014) as was observed in this study where the three maize varieties generally had significant variation on the phenology of maize. Omankwa which reached physiological maturity about 15 days before Obatanpa and about 30 days before Ahomatea (local variety) gave the indication that varieties differ in their phenological attributes. Kpotor (2012) made similar observations when she reported that hybrids, OPVs, local and inbred lines have varying days for the phenological traits. Thus, a given phenological stage of development can be predicted for a given variety under optimum climatic conditions (Kisaka 2014).

The significantly fewer days for ASI observed for Omankwa confirmed that it was a drought tolerant variety compared to the other two varieties as suggested by Bolanos and Edmeades (1996). Omankwa was bred as an early maturing, drought tolerant variety, whiles Obatanpa was bred as an intermediate, streak and drought tolerant variety. The phenological parameters recorded in this study generally showed that, plants in the SDFZ had lesser number of days to each of the phenological phase compared to those in the CSZ. This was probably due to the higher total annual rainfall recorded during the growth period in the SDFZ (716.7 mm) compared to that in the CSZ (601.3 mm). The amount of rainfall could therefore play a significant role in the phenological stages of the maize crop. This observation is in agreement with findings made by Kisaka (2014) who reported that rainfall amounts received during a growing season has a direct impact on the growth cycle of maize and that intra-seasonal rainfall distribution and variability and its impacts on maize development must be understood. Weber et al. (2012) and Cairns et al. (2013) observed that lack of water before and after anthesis result in significant yield losses. Bewket (2009) also reported that the duration to a given phenological stage is highly reliant on the amount and distribution of temporal rainfall received towards the stage. In this current study, there was good rainfall distribution in all the months during the growth period of the maize.

### *Growth*

The rate of growth which increased rapidly with time during the vegetative phase of this study, up to 7 and 9 WAS (depending on the variety) after which it slowed down was in agreement with the findings of Quansah (2010) who reported that, normally the growth of cereals follows a particular pattern; in that they exhibit rapid growth during the vegetative phase followed by a slow growth rate as the reproductive phase is initiated.

Even though Ahomatea had the tallest plant height in both AEZs, it produced the lowest grain yields. This observation could be due to the genetic makeup of Ahomatea. The differences in maturity dates of the different varieties could also be responsible for their growth trends. Omankwa matured earlier compared to the other varieties so it is possible that from 7 WAS it started to channel the essential nutrients needed for the reproductive phase from the various parts of the plant which may have limited the rate of vegetative growth.

***Yield***

The observed higher grain yields produced by Omankwa and Obatanpa which are all OPVs compared to the local variety (Ahomatea) across all the AEZs is in conformity with observations made by Kpotor, (2012) and Ewool et al. (2016) who found that OPVs are high yielding than local varieties. Ewool et al. (2016), observed a 40.5% yield advantage of Obatanpa over the 'Ohawu' local variety. This finding was similar to the current study where Obatanpa had yield advantage (ranging from 33.1 to 38.3%) over the 'Ahomatea' local variety.

Although the yield potential of the local variety is comparatively low, almost all the soil amendments applied improved its yields above the national average maize yield of 1.92 t ha $^{-1}$ (MoFA, 2016). This implies that even though the local variety has inherently low yields, its production can be boosted with application of additional soil nutrients. Obatanpa and Omankwa gave similar yields. These two varieties can therefore achieve higher grain yields when given the needed nutrient boost. The Obatanpa variety was released in 1992 but it is still very popular among the farmers. The Obatanpa is however an overused variety according to Ragasa et al. (2014). The Omankwa which was released in 2010 is an early maturing variety and drought resistant. These qualities make Omankwa a versatile variety in this era of climate change.

### 4.5.2. Effect of inorganic fertilizer and/or goat manure on phenology, growth and yield of maize in two agro-ecological zones

The goat manure used for this study, had a C/N ratio of 12.03 suggesting that it could potentially release N to increase the low N content of the soil for improved maize growth and yield as reported by Myers et al. (1994). Myers et al. (1994) reported that, a C/N ratio < 25 implies that the manure is of good quality and its decomposition could release mineral N. The response of the maize varieties to manure application in these soils was therefore anticipated.

### *Phenology*

For all the varieties, the sole fertilizer and fertilizer + manure treatments generally accelerated anthesis, silking and physiological maturity. Similarly, Cock and Ellis (1992) also reported that sufficient N results in rapid growth and hastens tasseling, while too little or no N, results in slow growth and delayed tasseling. This could be the reason why in this study, plants on the control plots (no amendments) took relatively longer period of time for number of days to 50% anthesis, silking and physiological maturity than plants on the soil with added nutrients for all the varieties. The general observation that the sole fertilizer and fertilizer + manure treatments triggered relatively earlier tasselling, silking and physiological maturity within each variety compared to the sole manure and control plots suggest that the fertilizer hastened the number of days for all the phenological parameters studied. Kanton et al. (2016) observed that maize plants on the chemical fertilizer-treated plots tassel and silk much earlier than plots treated with organic fertilizers alone, and that this phenomenon is very important in prolonging the reproductive phase for obtaining higher maize yield. The number of days to 50% physiological maturity which showed no significant differences for the different soil amendment in the major season was similar to findings by Nurudeen (2011) who also reported that, the increasing rate of NPK fertilizer did not show any significant difference among the treatments on number of days to physiological maturity.

### *Growth*

The observed increases in plant height, stem girth and leaf area for plots with added nutrients over the control suggests that, the inorganic fertilizer and manure provided extra nutrients which enhanced the cell activities (multiplication and enlargement) and transformed into rapid increase in plant height and stem girth as reported by Fashina et al. (2002). This finding is also in line with that of Yin et al. (2011) that, plant height is a key indicator of plant growth and is linked to nitrogen nutrition status during vegetative development of maize. The taller plant height and bigger stem girth observed under sole fertilizer treatments shows the effectiveness of the inorganic fertilizer in enhancing growth because nutrients are released faster. Nitrogen was found to increase number of nodes as well as internode length and consequently plant height (Jaja & Ibeawuch, 2015).

In this study, the reduction in stem girth which occurred from 7 to 11 in Omankwa and 9 to 11 WAS for Obatanpa is in agreement with findings by Quansah (2010) and Tanimu et al. (2013) who reported that, the reduction in stem girth during the reproductive phase of maize can be attributed to the translocation of essential minerals and nutrients to grain formation.

The leaves serve as photosynthetic organs of the plant and it plays an important role in regulating plant growth and development. Leaf area development is therefore an important parameter that affects maize grain yield and yield components (Akmal et al., 2010). The leaf area in maize was significantly influenced by inorganic fertilizers and manure at different stages of crop growth. Cox et al (1993) reported that higher rate of nitrogen promotes leaf area during vegetative development and also helps maintain functional leaf area during the growth period. This was probably the reason that leaf area was larger with the application of 100% NPK and 50% NPK + 50% goat manure compared to the control.

### *Yield*

Generally, all the varieties studied showed appreciable increases in yield in response to added nutrients to the soil, indicating the importance of fertilizer and or manure application in maize production. However, the yields varied depending upon variety, location and type of soil amendments.

The observation that, grain and stover yields for all the varieties used in this study followed this trend; sole fertilizer > fertilizer + manure > sole manure > control was probably due to the fact that under 100 % NPK treatment, nutrients were readily available for easy uptake by the plants. This might have enhanced increased photosynthetic efficiency of the plants and faster growth and development. The observation from this current work where plants on sole mineral fertilizer had higher grain yields compared to those on the sole manure plot is in agreement with work done by Uwah and Eyo (2014) who reported that the inorganic fertilizer alone significantly increased growth and yield of maize than the sole manure treatment in both seasons. Quansah (2010) however observed that the combined applications of organic and inorganic fertilizer produce yields, which are significantly higher than organic or inorganic alone in the major season (first cropping). The observation by Quansah (2010) could be due to the type of organic manure (poultry manure) used.

The relatively positive response of all the three maize varieties to application of inorganic fertilizer either alone or in combination with manure evident by comparatively higher grain yields was probably due to the initial low fertility status of the soils on which the experiments were carried out. The experimental sites had been continuously cropped for long periods without inclusion of soil amendments and so lacked essential nutrients. Adediran et al. (2004) made similar observations when they reported that the greater yield increase from the mineral fertilizer during the first cropping cycle might be due to its ability to make nutrients more readily available to crop plants than the organic manures. This was corroborated by Okigbo (2000) who also reported that inorganic fertilizers ensure quick availability of nutrients to crops even though they have limited residual effect of the applied nutrients. Manure either alone or in combination with mineral fertilizer are known to leave residual nutrients in the soil or also improve soil organic matter content (Cooke, 1970 cited by Quansah, 2010). Therefore farmers in the study areas where the soils were generally low in organic matter and other nutrients will benefit greatly from application of manure either alone or in combination with mineral fertilizers for sustainable production.

The result of this current study indicates that, goat manure at a rate of 5 t ha$^{-1}$ had the potential to improve maize yields significantly over the control treatments. The yields of maize with goat manure as the sole soil amendment, increased yields by about 36.6% in SDFZ and 33.6% in the CSZ over the control when averaged for the varieties in the major season indicating that nutrient availability was improved as a result of goat manure application alone. This result agrees with the finding of Uwah and Eyo (2014) that goat manure increase yields of sweet maize. Odiete et al. (1999) also reported that goat manure increase yield of okra, amaranthus and maize in southwest Nigeria. The use of animal manure has been reported to improve soil fertility and increase maize yields in northern Ghana (Abunyewa & Karbo, 2005). It is being advocated that in instances where the farmers cannot afford commercial fertilizers (as was observed in the study areas), the use of farm yard manure alone must be encouraged since it could increase yields ranging from 21.5 to 41.8% depending on the variety rather than not applying any soil amendments. Furthermore, the use of manure alone or in combination with inorganic fertilizer contributes to sustainable maize production by providing considerable quantities of plant nutrients including micro nutrients (Ibeawuchi et al., 2006). It must be noted however that, the nutrient content of manure varies, and the reason is that the nutrient value of manure is greatly affected by diet of animal, amount of bedding, storage and application method (Harris et al., 2001) as well as rate of application.

Ayuke et al. (2004) reported that fertilizer use increase maize grain yield by 63% over the control. In this current study, sole fertilizer applied increased maize grain yield by values ranging from 61.2 to 86.8% over the control even though Ayuke et al. (2004) used relatively higher quantities of mineral fertilizers (120 kg N, 150 kg P and 100 kg K ha-1) compared to what was used in the current study (95 kg N, 37.5 kg P and 37.5 kg K).

### 4.6. Chapter Summary

The study conducted in the CSZ and SDFZ in the Central and Eastern regions of Ghana respectively in the major season are summarised below:

- The major season experiment showed that most of the growth and yield parameters measured were significantly higher for plants on the sole inorganic fertilizer plots among the different soil amendments tested.

- Use of sole inorganic fertilizer increased maize grain yields by values ranging from 61.2 to 86.2% over the control in both AEZ.
- The application of sole manure at 5 t $ha^{-1}$ was effective in terms of increasing maize yields over the control by values ranging from 21.5 to 41.8%.
- All the varieties used for this study had their highest grain yields on the sole inorganic fertilizer in both the SDFZ and CSZ.
- Plants on the control plots obtained the lowest grain yields in the SDFZ and the CSZ.
- On the average, Omankwa variety gave the highest yields, had the shortest ASI and matured earliest.
- Even though the yield potential of the local variety is comparatively low, almost all the soil amendments improved its yields above the current national average yields.
- Grain and stover yields were generally higher in the SDFZ than in the CSZ.

# CHAPTER FIVE

# INFLUENCE OF INORGANIC FERTILIZER AND ORGANIC MANURE AND THEIR RESIDUAL EFFECT ON THE GROWTH AND YIELD OF MAIZE IN THE SEMI-DECIDUOUS FOREST AND THE COASTAL SAVANNAH AGRO ECOLOGICAL ZONES OF GHANA

## 5.1. Introduction

Declining soil fertility in sub-Saharan Africa (SSA) and Ghana in particular has assumed prominence in recent times mainly due to continuous cropping on the same piece of land with little or total absence of soil amendments. Smallholder farmers typically are resource poor so improving food production and soil resources in the smallholder farm sector of Africa has become an enormous challenge (Smaling & Braun, 1996). Mutegi et al. (2012) reported that, soil fertility depletion in smallholder farms is the fundamental biophysical root cause for declining per capita food production in SSA.

The need to ameliorate these soils for increased maize productivity can therefore not be overemphasized. The majority of smallholder farmers on the other hand, lack the financial resources to purchase sufficient mineral fertilizers to replace the soil nutrients exported with harvested crop produce (Mutegi et al., 2012) and those who can afford hardly use the recommended rates.

Long-term experiments have shown that with no fertilizer use, yields decline rapidly from an initial level of 5 t ha$^{-1}$ to about 1 t ha$^{-1}$ after 3 years (Waddington et al., 2007) indicating the importance of soil amelioration for continuous cropping. Many studies in SSA have reported on the positive interaction between fertilizer and manure, with the benefits of manure increasing with decreasing soil fertility (Zingore et al., 2008; Mtambanengwe & Mapfumo, 2005).

Understanding the response of maize to recommended fertilizer rates and or manure and their residual effects in a given AEZ has vital role in enhancing maize production and productivity on sustainable basis. Quansah (2010) reported that residual nutrients sustain maize plant growth and has yields, which are approximately 50% lower than yields obtained from initial nutrient application.

A survey of smallholder farmers in the semi-deciduous forest and coastal savannah AEZs revealed that, those who apply fertilizer on maize plots in the major season do not re-apply in the minor season with the explanation that nutrients applied in the major season would cater for plants sown in the minor season. This study sought to verify this assertion.

Further, there are research works on the effect of organic or inorganic fertilizers on maize growth and yield but there is rarely available information on the residual effect of these soil amendments and their combination on maize in the SDFZ and CSZ.

## 5.2. Objectives

The objective of this study was to evaluate the effect of minor season application of soil amendments (inorganic fertilizer, goat manure and their combination) and also their residual effect (for plots that received soil amendments in the major season) on the performance of three maize varieties in the SDFZ and CSZ of Ghana.

## 5.3. Materials and methods

The study was conducted as a researcher managed on-farm trial at the CSZ and SDFZ at three sites per AEZ in the minor season of 2017. The experiment was conducted from September 2017 to January 2018 as a participatory action research. At each experimental site, one farmer was chosen and together with the agricultural extension agent in the community, helped with supervision of the experimental farm as well as some data collection.

### 5.3.1. Study areas:

The study areas are same as in the major season experiment.

### 5.3.2. Field experiments

The experiments were conducted in the six communities where the major season experiments were undertaken. All the experimental fields had previously been used for maize cultivation in the major season of 2017.

### 5.3.3. Land preparation and weed management

The old maize stalk from the previous seasons planting was slashed with machete just after harvesting and weedicide (glyphosate) applied immediately to the undergrowth at the rate of 1.5 kg ha$^{-1}$ to control weeds on the fields. The field was then marked out into plots. Post planting weed management was the same as in the major season.

### 5.3.4. Experimental design and treatment

The experiment was laid out in a split plot with four replications at each site. Each of the initial plots in the major season was split into two. There were four rows on each side separated by 0.80 m. The new plot now had four rows, 5.6 m long, with a planting distance of 0. 80 m x 0.40 m. Sowing was done between 12th and 16th September, 2017 in both AEZs. Three seeds per hill were sown and later thinned to two plants per hill at 14 days after sowing, giving a total plant population of 62,500 plants per hectare.

Experimental materials and soil amendments applied were same as in the major season. In this experiment however, each plot had been split into two and one had the soil amendments applied (same as in the major season) and the other was without the amendments (residual nutrients treatment) even though it had received amendments in the major season. The control plots were however not split into two. This design gave a total of 7 treatments per variety with four replications in the minor season of 2017. The rates of application of the soil amendments were the same as in the major season (Chapter 4).

**Table 5.1: Soil amendments and treatment codes used for tables in the minor season**

| Soil amendment | Treatment name | Treatment code |
|---|---|---|
| 1. NPK fertilizer ( 15-15-15) + N (Urea)(Sole fertilizer) | Fertilizer | F |
| 2. Goat manure ( GM) | Manure | GM |
| 3. 50% GM+50% NPK+50% Urea (Fertilizer +Manure) | Fert +manure | F+GM |
| 4. Residual nutrient sole fertilizer | Res fertilizer | RNSF |
| 5. Residual nutrients goat manure | Res manure | RNGM |
| 6. Residual nutrients fertilizer + goat manure | Res fert + manure | RNF+GM |
| 7. Control (No amendment) | Control | C |

Source: Field data, Marfo-Ahenkora (2018)

### 5.3.5. Data Collection

Rainfall data was collected during the period of the experiment. Data on maize phenology, growth, yield, and yield components were recorded for the minor growing season as described in Chapter 4.

### *Phenology records*

Phenological data such as days to 50% anthesis, days to 50% silking, anthesis-silking interval (ASI) and days to physiological maturity were recorded at all the experimental sites as described in Chapter 4.

### *Growth measurements*

The growth data collected in the minor season were plant height, stem girth, number of leaves, leaf area and then leaf area index was calculated. The methodology for the growth measurements was the same as in the major season. In the minor season, growth data measurements began at 5 weeks after sowing (WAS) on 17th October and ended on 28th November 2017 in the SDFZ. In the CSZ growth measurements began at 5 WAS on 21st October, 2017 and ended on 2nd December 2017.

### *Yield parameters*

At maturity, maize ears and stalks were harvested. Harvesting of Omankwa was done on 20th December 2017 in the SDFZ. Obatanpa and landrace (local varieties) were harvested on, 6th January and 13th January, 2018 respectively in the SDFZ. In the CSZ, Omankwa, Obatanpa and local varieties were harvested on 22nd December, 2017, 9th January and 15th January, 2018 respectively.

Data on yield and yield components such as 1000 grain weight, grain yield, stover yield, cobs per plants, mean number of kernels per cob, mean number of kernels per row, mean number of kernel rows per cob, mean cob weight, mean cob diameter, and mean cob length were recorded for the minor season as described in Chapter 4.

### 5.3.6. Data Analysis

The data collected from the field were subjected to analysis of variance (ANOVA) to establish single and interactive effects on maize phenology, growth and yield. The ANOVA was performed separately for each AEZ. Data were later combined across the AEZs and analysed for measured parameters. Treatment means were separated using Tukey's honest significance test at 5% level of probability. The standard error of the difference (SED) was used for the error bars for the graphs. Statistical analyses were performed using the GenStat statistical package (GenStat, 12th edition, 2009). Graphs were constructed using Microsoft Excel Office 2010.

## 5.4. Results

Rainfall amounts and mean temperature recorded during the minor season experimentation are documented in Figure 4.2 and Table 4.6. Total rainfall of 384.67 mm and 331.1 mm was received from planting to physiological maturity (September to December) in the SDFZ and CSZ respectively. In the minor season, the rains peaked in October in both zones.

### 5.4.1. Phenology of three maize varieties under different soil amendments in the SDFZ and CSZ.

Results of phenological features such as anthesis, silking, anthesis–silking interval and physiological maturity of three maize varieties under different soil amendments in the two AEZs have been presented in Tables 5.2. Significant differences ($P < 0.001$) were observed among the varieties and soil amendments but not on their interactions for days to 50% anthesis, silking and physiological maturity of maize in both AEZs.

**Table 5.2** Phenology of three maize varieties on four soil amendments in the Coastal savannah (CSZ) and Semi-deciduous forest zone (SDFZ).

| Tream Treatments | No of days to 50% Anthesis | | No of days to 50% silking | | Anthesis-Silking interval (ASI) | | Days to physiological maturity | |
|---|---|---|---|---|---|---|---|---|
| **Varieties** | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ |
| Ahomatea | 57.9 | 56.4 | 63.4 | 61.7 | 5.5 | 5.3 | 124.1 | 121.8 |
| Obatanpa | 55.9 | 54.8 | 61.0 | 59.9 | 5.1 | 5.1 | 106.9 | 105.4 |
| Omankwa | 46.8 | 44.9 | 50.1 | 47.8 | 3.3 | 2.9 | 93.1 | 91.4 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 0.90 | 0.90 | 1.08 | 1.08 | 0.53 | 0.53 | 1.22 | 1.22 |
| **Soil amendments** | | | | | | | | |
| Fert +manure | 53.0 | 50.8 | 57.1 | 54.8 | 4.1 | 3.9 | 105.9 | 104.1 |
| Fertilizer | 52.0 | 51.8 | 56.3 | 55.8 | 4.3 | 3.9 | 106.0 | 104.2 |
| Manure | 53.2 | 51.5 | 58 | 56.0 | 4.7 | 4.4 | 107.4 | 105.7 |
| Res Manure | 53.9 | 52.4 | 58.7 | 57.1 | 4.7 | 4.6 | 108.8 | 107.3 |
| Res Fert +Manure | 53.8 | 52.7 | 58.6 | 57.4 | 4.9 | 4.8 | 109.0 | 106.8 |
| Res fertilizer | 54.0 | 51.4 | 58.8 | 56.2 | 4.8 | 4.7 | 109.2 | 106.8 |
| Control | 54.7 | 53.5 | 59.6 | 58.2 | 4.9 | 4.7 | 109.8 | 108.3 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | 0.064 | 0.064 | <0.001 | <0.001 |
| Tukey (5%) | 1.44 | 1.44 | 1.38 | 1.38 | - | - | 3.02 | 3.02 |

Source: Field data, Marfo-Ahenkora (2018)

### *Mean number of days to 50% anthesis*

The variety × soil amendment interaction was not significant (P = 0.99) for number of days to 50% anthesis. There were however significant (P <0.001) differences among the varieties for days to 50% anthesis. Omankwa had significantly (P <0.001) fewer days (46.7 days in CSZ and 44.9 in SDFZ days) to 50% anthesis compared to Obatanpa and Ahomatea. Ahomatea had the most number of days (57.9 days in the CSZ and 56.4 days in the SDFZ) to 50% anthesis and was significantly different from Obatanpa.

The different soil amendments significantly (P <0.001) influenced the number of days to 50% anthesis in both AEZs. Plants on the control plots had significantly (P <0.001) more number of days to 50% anthesis than that of plants on the sole fertilizer and fertilizer + manure treatments in both AEZs. There were no significant differences for number of days to 50% anthesis among plants on the sole fertilizer, fertilizer + manure and sole manure treatments in both AEZs. Further, there were no significant differences for days to 50% anthesis among plants on residual nutrients in both AEZs (Table 5.2).

### ***Mean number of days to 50% silking***

The variety × soil amendment interaction was not significant (P = 0.95) for days to 50% silking. There were however significant (P <0.001) differences among the varieties for days to 50% silking. Omankwa had significantly (P<0.001) fewer number of days (50.1 days in the CSZ and 47.8 days in the SDFZ) to 50% silking compared to Obatanpa and Ahomatea. Ahomatea had the most number of days (63.4 days in the CSZ and 61.7 days in the SDFZ) to 50% silking and was significantly different from Obatanpa in both the SDFZ and CSZ.

Application of soil amendments significantly (P <0.001) influenced number of days to 50% silking. Plants on the sole fertilizer and fertilizer + manure plots were not significantly different from each other for days to 50% silking in both AEZs. Plants on the control plots had the most number of days to 50% silking in both AEZs. Generally, application of inorganic fertilizer either in combination with manure or as sole fertilizer significantly (P <0.001) decreased the number of days to silking compared to plants on the residual nutrients and control plots except for plants on residual sole fertilizer in the SDFZ (Table 5.2).

### *Anthesis-Silking Interval (ASI)*

The variety × soil amendment interaction was not significant (P = 0.05) for ASI. Significant (P <0.001) differences were however observed among the maize varieties for ASI with Omankwa having the shortest intervals for ASI (3.3 days in the CSZ and 2.9 days in the SDFZ) which was significantly (P <0.001) shorter than that of Obatanpa and Ahomatea. Although Ahomatea had the longest interval for ASI (5.5 days in the CSZ and 5.3 in the SDFZ) there was no significant difference between Ahomatea and Obatanpa in both AEZs. Soil amendments did not show any significant (P=0.06) difference for ASI (Table 5.2).

### ***Mean number of days to physiological maturity***

The variety × soil amendment interaction was not significant (P = 1.00) for days to physiological maturity. There was however significant (P < 0.001) difference for variety for days to physiological maturity. Among the varieties, Ahomatea had significantly (P < 0.001) more days (124.1 days in the CSZ and 121.8 days in the SDFZ) to physiological maturity whiles Omankwa had significantly (P < 0.001) less number of days (93.1 days in the CSZ and 91.4 days in the SDFZ) to physiological maturity.

Days to physiological maturity was significantly influenced by soil amendments in both AEZs. Plants on the sole fertilizer and fertilizer + manure plots had significantly (P < 0.001) fewer days to physiological maturity compared to the control in both the SDFZ and CSZ (Table 5.2).

### 5.4.2. Growth parameters of three maize varieties under different soil amendments in the SDFZ and CSZ in the minor season.

Results of growth parameters; plant height, stem girth and leaf area for 5, 7, 9 and 11 weeks after sowing (WAS) in the SDFZ and CSZ in the minor season are presented in Tables 5.3 to 5.5.

***Mean plant height***

Mean plant heights recorded for Ahomatea, Obatanpa and Omankwa in the SDFZ and CSZ showed that there were significant differences for variety at 5 WAS ($P < 0.001$), 7 WAS ($P < 0.001$), 9 WAS ($P < 0.001$) and 11 WAS ($P < 0.001$) for plant height in both AEZs.

Plant height was influenced significantly by soil amendments at 5 WAS ($P < 0.001$), 7 WAS ($P < 0.001$), 9 WAS ($P < 0.001$) and 11 WAS ($P < 0.001$) in both AEZs. Plant heights for Ahomatea, Obatanpa and Omankwa for plants on sole fertilizer plots were not significantly different from those on the fertilizer + manure plots except for Omankwa at 5 WAS in the SDFZ where plant height for plants on sole fertilizer and fertilizer + manure were significantly ($P < 0.001$) different. Further, plant height for all the varieties on sole fertilizer and fertilizer + manure were significantly ($P < 0.001$) taller than plants on all the residual nutrients and the control plots for all the weeks after sowing and in both CSZ and SDFZ except for Omankwa at 9 WAS where plants on sole fertilizer and residual manure plots were not significantly different.

**Table 5.3: Mean plant height of Ahomatea, Obatanpa and Omankwa on different soil amendments at 5, 7, 9 and 11 WAS in the CSZ and SDFZ**

| Treatments | Coastal savannah | | | | Semi deciduous forest | | | |
|---|---|---|---|---|---|---|---|---|
| | Weeks after sowing | | | | Weeks after sowing | | | |
| **Ahomatea** | 5 | 7 | 9 | 11 | 5 | 7 | 9 | 11 |
| Fert+manure | 127.7 | 224.7 | 237.3 | 240.8 | 135.9 | 231.4 | 247.0 | 249.4 |
| Fertilizer | 125.5 | 217.3 | 233.7 | 235.9 | 130.8 | 223.4 | 240.4 | 242.3 |
| Manure | 120.7 | 208.1 | 226.9 | 228.2 | 124.5 | 215.8 | 232.2 | 235.4 |
| Res Manure | 113.1 | 197.8 | 218.4 | 220.5 | 120.9 | 210.8 | 226.0 | 227.6 |
| Res Fert +manure | 109.8 | 191.2 | 215.2 | 217.1 | 117.9 | 201.1 | 218.0 | 219.9 |
| Res Fertilizer | 103.8 | 186.6 | 213.8 | 215.2 | 115.5 | 193.4 | 210.1 | 212.7 |
| Control | 97.4 | 173.6 | 207.6 | 210.0 | 110.4 | 186.3 | 203.1 | 205.4 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 6.54 | 10.53 | 10.56 | 10.69 | 6.54 | 10.53 | 10.56 | 10.69 |
| **Obatanpa** | | | | | | | | |
| Fert+manure | 137.1 | 228.8 | 231.1 | 233.5 | 150.2 | 235.5 | 244.5 | 246.2 |
| Fertilizer | 130.7 | 223.6 | 228.1 | 230.1 | 144.8 | 230.7 | 239.0 | 241.2 |
| Manure | 123.2 | 215.5 | 222.8 | 225.4 | 136.3 | 226.8 | 232.4 | 234.2 |
| Res Manure | 116.2 | 204.7 | 214.1 | 216.7 | 130.1 | 216.2 | 225.6 | 227.2 |
| Res Fert +manure | 112.9 | 197.0 | 210.4 | 213.2 | 125.1 | 210.4 | 220.2 | 222.8 |
| Res Fertilizer | 108.6 | 192.2 | 205.7 | 207.9 | 121.5 | 200.4 | 214.6 | 217.4 |
| Control | 105.5 | 187.5 | 201.0 | 204.5 | 114.4 | 194.8 | 210.8 | 213.9 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 6.54 | 10.53 | 10.56 | 10.69 | 6.54 | 10.53 | 10.56 | 10.69 |
| **Omankwa** | | | | | | | | |
| Fert+manure | 130.6 | 212.1 | 221.4 | 221.6 | 134.6 | 215.9 | 226.4 | 227.1 |
| Fertilizer | 124.6 | 202.2 | 216.6 | 217.0 | 127.2 | 209.9 | 219.8 | 220.3 |
| Manure | 120.4 | 192.6 | 212.5 | 212.9 | 122.3 | 201.6 | 212.8 | 213.0 |
| Res Manure | 108.0 | 186.8 | 206.6 | 207.1 | 119.8 | 195.3 | 207.4 | 208.1 |
| Res Fert +manure | 106.8 | 182.0 | 199.7 | 200.6 | 115.7 | 190.2 | 205.5 | 206.5 |
| Res Fertilizer | 102.2 | 176.4 | 192.4 | 192.9 | 110.2 | 179.0 | 200.9 | 201.3 |
| Control | 100.9 | 170.1 | 187.3 | 188.5 | 107.1 | 173.1 | 195.9 | 196.3 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 6.54 | 10.53 | 10.56 | 10.69 | 6.54 | 10.53 | 10.56 | 10.69 |

Source: Field data, Marfo-Ahenkora (2018)

Generally, plant height for all the varieties followed a similar trend for soil amendment and was in the order of fertilizer + manure > sole fertilizer > sole manure > residual manure > residual fertilizer + manure > residual fertilizer > control. The growth trend of plant height for all varieties indicated that there was a rapid growth from 5 to 7 WAS for all the soil amendments, then a steady growth from 7 to 9 WAS and then very marginal height gains were recorded between 9 and 11 WAS for both the CSZ and SDFZ (Table 5.3).

***Mean stem girth (cm)***

Mean stem girth recorded for Ahomatea, Obatanpa and Omankwa in the SDFZ and CSZ are presented in Table 5.4. There were significant differences for variety at 5 WAS (P < 0.001), 7 WAS (P < 0.001), 9 WAS (P < 0.001) and 11 WAS (P < 0.001) for stem girth in both AEZs.

Stem girth was also influenced significantly by soil amendments at 5 WAS (P < 0.001), 7 WAS (P < 0.001), 9 WAS (P < 0.001) and 11 WAS (P < 0.001) in both AEZs.

Ahomatea had no significant differences among the applied nutrients (fert + manure, sole fertilizer, manure) for stem girth at 5 WAS. Plants on the residual nutrients (residual manure, residual fertilizer +manure, residual fertilizer) and control plots were also not significantly different at 5 WAS in both AEZs. Stem girth for plants on applied nutrients, residual nutrients and control plot were not significantly different from each other at 7, 9 and 11 WAS in both AEZs except at 7 WAS in both AEZs, 9 and 11 WAS at the CSZ where stem girth for plants on the fertilizer + manure treatment were significantly (P < 0.001) bigger than plants on the control plots (Table 5.4).

There were no significant differences among the applied nutrients (fertilizer + manure, sole fertilizer, sole manure) for stem girth of Obatanpa at 5 WAS and also among the residual nutrients in both AEZS. Stem girth of Obatanpa was not influenced significantly by all soil treatments except plants on the fertilizer + manure treatments which had significantly ($P < 0.001$) bigger stem girth than those on the control plots at 7,9 and 11 WAS in both AEZs. Stem girth of Obatanpa on sole fertilizer plot was also significantly ($P < 0.001$) bigger than that on the control plots at 9 and 11 WAS in the SDFZ.

Stem girth for Omankwa was not significantly different among plants on applied nutrients for all the weeks after sowing. Similar observation was made among plants on the residual nutrients and control plots except stem girth of plants on residual manure plots which was significantly different from plants on the control plots at 7, 9 and 11 WAS in the CSZ. Stem girth of plants on applied nutrients (fertilizer + manure, sole fertilizer, sole manure) were also significantly ($P < 0.001$) bigger than those on the control plots for all weeks after sowing and in both AEZs (Table 5.4).

For all the varieties, plants on the fert +manure plots had the biggest stem girth while those on the control plots had the smallest stem girth for all the weeks after sowing and in both AEZs. The growth trend of stem girth for all varieties showed that there was a rapid growth from 5 to 7 WAS for all the soil amendments, then a steady growth from 7 to 9 WAS and then a decrease in girth was recorded between 9 and 11 WAS for both the CSZ and SDFZ (Table 5.4).

Table 5.4 Mean stem girth of Ahomatea, Obatanpa and Omankwa on different soil amendments at 5, 7, 9 and 11 WAS in the CSZ and SDFZ

| Treatments | Coastal savannah | | | | Semi deciduous forest | | | |
|---|---|---|---|---|---|---|---|---|
| Soil amendments | Weeks after sowing | | | | Weeks after sowing | | | |
| **Ahomatea** | 5 | 7 | 9 | 11 | 5 | 7 | 9 | 11 |
| Fert+manure | 7.28 | 7.78 | 7.96 | 7.74 | 7.39 | 7.87 | 7.99 | 7.80 |
| Fertilizer | 7.08 | 7.70 | 7.86 | 7.68 | 7.30 | 7.78 | 7.86 | 7.70 |
| Manure | 6.91 | 7.60 | 7.80 | 7.61 | 7.21 | 7.70 | 7.81 | 7.65 |
| Res Manure | 6.77 | 7.47 | 7.71 | 7.54 | 7.07 | 7.61 | 7.73 | 7.55 |
| Res Fert +manure | 6.65 | 7.41 | 7.64 | 7.35 | 6.91 | 7.52 | 7.66 | 7.48 |
| Res Fertilizer | 6.54 | 7.32 | 7.53 | 7.21 | 6.84 | 7.41 | 7.58 | 7.40 |
| Control | 6.39 | 7.25 | 7.45 | 7.16 | 6.76 | 7.35 | 7.50 | 7.35 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 0.436 | 0.480 | 0.498 | 0.492 | 0.436 | 0.480 | 0.498 | 0.492 |
| **Obatanpa** | | | | | | | | |
| Fert+manure | 7.41 | 7.97 | 8.23 | 7.98 | 7.57 | 8.19 | 8.41 | 8.20 |
| Fertilizer | 7.27 | 7.79 | 8.15 | 7.85 | 7.41 | 8.09 | 8.29 | 8.07 |
| Manure | 7.15 | 7.68 | 8.05 | 7.76 | 7.29 | 7.98 | 8.11 | 7.91 |
| Res Manure | 7.04 | 7.59 | 7.91 | 7.69 | 7.17 | 7.89 | 7.97 | 7.74 |
| Res Fert +manure | 6.92 | 7.50 | 7.83 | 7.64 | 7.08 | 7.80 | 7.89 | 7.67 |
| Res Fertilizer | 6.81 | 7.44 | 7.75 | 7.53 | 6.95 | 7.69 | 7.81 | 7.63 |
| Control | 6.71 | 7.31 | 7.68 | 7.47 | 6.84 | 7.61 | 7.69 | 7.48 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 0.436 | 0.480 | 0.498 | 0.492 | 0.436 | 0.480 | 0.498 | 0.492 |
| **Omankwa** | | | | | | | | |
| Fert+manure | 7.35 | 7.88 | 7.55 | 7.43 | 7.38 | 7.89 | 7.61 | 7.48 |
| Fertilizer | 7.22 | 7.75 | 7.46 | 7.36 | 7.26 | 7.83 | 7.55 | 7.42 |
| Manure | 7.16 | 7.65 | 7.31 | 7.23 | 7.21 | 7.74 | 7.45 | 7.37 |
| Res Manure | 7.01 | 7.47 | 7.19 | 7.08 | 7.09 | 7.64 | 7.36 | 7.23 |
| Res Fert +manure | 6.87 | 7.25 | 6.98 | 6.86 | 6.90 | 7.48 | 7.20 | 7.08 |
| Res Fertilizer | 6.74 | 7.08 | 6.82 | 6.69 | 6.81 | 7.32 | 7.04 | 6.91 |
| Control | 6.62 | 6.93 | 6.67 | 6.55 | 6.73 | 7.18 | 6.88 | 6.79 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 0.436 | 0.480 | 0.498 | 0.492 | 0.436 | 0.480 | 0.498 | 0.492 |

Source: Field data, Marfo-Ahenkora (2018)

### *Mean leaf area ($cm^{-2}$)*

Leaf area was influenced significantly by soil amendments at 5 WAS ($P < 0.001$), 7 WAS ($P < 0.001$), 9 WAS ($P < 0.001$) and 11 WAS ($P < 0.001$) in both AEZs (Table 5.5). Leaf area for Ahomatea on the fertilizer + manure plots was significantly ($P < 0.001$) larger than that of all the treatments for all the weeks after sowing and for both AEZs except for sole fertilizer at 5 WAS in the SDFZ and 9 WAS in the CSZ. Ahomatea on control plots generally had significantly ($P < 0.001$) smaller leaf area compared to the rest of the treatments.

Plants on Obatanpa followed a similar trend like Ahomatea where leaf area on fertilizer + manure plots were significantly ($P < 0.001$) larger than those on the rest of the treatments except for sole fertilizer at 5 WAS in the CSZ and 11 WAS in both AEZs. Plants on the control plots had significantly ($P < 0.001$) smaller leaf area except at 7 and 11 WAS in the SDFZ where it was not significantly different from leaf area of plants on the residual fertilizer treatments.

Leaf area of Omankwa on sole fertilizer and the fertilizer + manure plots were not significantly different from each other but they had significantly ($P < 0.001$) larger leaf area than the rest of the soil amendments except at 9 WAS in the CSZ where plants on fertilizer + manure plots had significantly ($P < 0.001$) larger leaf area than that of sole fertilizer. Plants on the control plots had the smallest leaf area which was significantly ($P < 0.001$) different from the rest of the soil amendment at 5 WAS in both AEZs, 7 and 11 WAS in the CSZ.

The growth trend of leaf area for all varieties showed that there was a rapid growth from 5 to 7 WAS for all the soil amendments, then a steady growth from 7 to 9 WAS and then a decrease in leaf area was recorded between 9 and 11 WAS in both the CSZ and SDFZ (Table 5.5).

**Table 5.5 Mean leaf area of Ahomatea, Obatanpa and Omankwa on different soil amendments at 5, 7, 9 and 11 WAS in the CSZ and SDFZ**

| Treatments | Coastal savannah | | | | Semi deciduous forest | | | |
|---|---|---|---|---|---|---|---|---|
| Soil amendments | Weeks after sowing | | | | Weeks after sowing | | | |
| **Ahomatea** | 5 | 7 | 9 | 11 | 5 | 7 | 9 | 11 |
| Fert+manure | 2296 | 5309 | 5489 | 4504 | 2497 | 5571 | 5879 | 4913 |
| Fertilizer | 2103 | 4985 | 5367 | 4288 | 2387 | 5289 | 5655 | 4623 |
| Manure | 1959 | 4676 | 5179 | 4122 | 2170 | 4880 | 5359 | 4286 |
| Res Manure | 1683 | 4319 | 4822 | 3798 | 1869 | 4666 | 5089 | 4058 |
| Res Fert +manure | 1542 | 4023 | 4546 | 3662 | 1756 | 4352 | 4858 | 3798 |
| Res Fertilizer | 1411 | 3732 | 4251 | 3192 | 1647 | 4052 | 4508 | 3490 |
| Control | 1155 | 3419 | 3969 | 2822 | 1466 | 3858 | 4325 | 3289 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 122.8 | 214.8 | 191.3 | 203.3 | 122.8 | 214.8 | 191.3 | 203.3 |
| **Obatanpa** | | | | | | | | |
| Fert+manure | 2383 | 5421 | 5683 | 4329 | 2458 | 5621 | 5741 | 4682 |
| Fertilizer | 2274 | 5097 | 5282 | 4156 | 2353 | 5343 | 5512 | 4498 |
| Manure | 2021 | 4789 | 5045 | 4001 | 2187 | 4932 | 5218 | 4286 |
| Res Manure | 1725 | 4453 | 4738 | 3864 | 1919 | 4742 | 4902 | 3946 |
| Res Fert +manure | 1615 | 4117 | 4452 | 3432 | 1702 | 4471 | 4751 | 3732 |
| Res Fertilizer | 1487 | 3816 | 4189 | 3166 | 1654 | 4119 | 4451 | 3449 |
| Control | 1251 | 3525 | 3857 | 2722 | 1324 | 3923 | 4245 | 3250 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 122.8 | 214.8 | 191.3 | 203.3 | 122.8 | 214.8 | 191.3 | 203.3 |
| **Omankwa** | | | | | | | | |
| Fert+manure | 2274 | 5287 | 5350 | 4134 | 2333 | 5437 | 5558 | 4467 |
| Fertilizer | 2188 | 4909 | 5091 | 3961 | 2231 | 5251 | 5398 | 4270 |
| Manure | 1999 | 4721 | 4931 | 3857 | 2009 | 4905 | 5046 | 3888 |
| Res Manure | 1876 | 4348 | 4562 | 3443 | 1901 | 4585 | 4667 | 3502 |
| Res Fert +manure | 1608 | 4084 | 4250 | 3123 | 1627 | 4320 | 4420 | 3301 |
| Res Fertilizer | 1543 | 3732 | 3808 | 2767 | 1560 | 4095 | 4249 | 3119 |
| Control | 1240 | 3477 | 3625 | 2447 | 1270 | 3892 | 4095 | 2923 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 122.8 | 214.8 | 191.3 | 203.3 | 122.8 | 214.8 | 191.3 | 203.3 |

Source: Field data, Marfo-Ahenkora (2018)

### 5.4.3. Effect of different soil amendments (inorganic fertilizer, goat manure and fertilizer + manure) and their residual nutrient on yield components and yield of three maize varieties in the minor season of 2017 in the SDFZ and CSZ.

Yield components Yield and of three maize varieties in response to different soil amendments have been presented in Tables 5.6-5.8 and Figure 5.1 to 5.3 Yield components were significantly ($P < 0.001$) influenced by variety and soil amendments but not the interaction between variety and soil amendment in both locations.

**Table 5.6: Yield components (number of cobs/plant, kernel rows/cob, kernels/row, kernels/cob) of three maize varieties under four soil amendments in the CSZ and SDFZ in the minor season**

| Treatments | No. of cobs per plant | | No. of kernel rows per cob | | No. of kernels per row | | No of kernels per cob | |
|---|---|---|---|---|---|---|---|---|
| **Varieties** | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ |
| Ahomatea | 1.03 | 1.04 | 13.2 | 13.4 | 29.1 | 30.1 | 391.0 | 405.5 |
| Obatanpa | 1.03 | 1.05 | 13.5 | 13.7 | 29.4 | 31.0 | 393.9 | 424.8 |
| Omankwa | 1.05 | 1.06 | 14.0 | 14.4 | 30.4 | 32.1 | 427.6 | 447.3 |
| P-value | 0.034 | 0.034 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 0.02 | 0.02 | 0.22 | 0.22 | 0.62 | 0.62 | 17.17 | 17.17 |
| **Soil amendments** | | | | | | | | |
| Fert + manure | 1.10 | 1.13 | 14.4 | 14.7 | 33.8 | 34.0 | 477.0 | 491.0 |
| Fertilizer | 1.09 | 1.09 | 14.2 | 14.5 | 32.6 | 33.5 | 470.1 | 481.0 |
| Manure | 1.03 | 1.05 | 14.1 | 14.2 | 31.1 | 31.5 | 435.1 | 447.4 |
| Res manure | 1.02 | 1.04 | 13.4 | 13.7 | 30.0 | 30.8 | 397.8 | 405.7 |
| Res fert +manure | 1.01 | 1.03 | 13.3 | 13.5 | 28.1 | 29.9 | 366.2 | 402.0 |
| Res fertilizer | 1.00 | 1.02 | 12.8 | 13.4 | 26.6 | 29.4 | 354.9 | 388.2 |
| Control | 1.00 | 1.01 | 13.0 | 12.9 | 25.2 | 28.4 | 327.9 | 365.8 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 0.03 | 0.03 | 0.47 | 0.47 | 0.94 | 0.94 | 20.49 | 20.49 |

Source: Field data, Marfo-Ahenkora (2018)

Similar cob numbers were observed irrespective of the variety or soil amendment used. However, the number of kernels per cob was better with Obatanpa and Omankwa than Ahomatea in both locations. Also planting maize with fertilizer + manure or only fertilizer resulted in a significantly ($P < 0.001$) higher number of kernels per cob in both locations (Table 5.6).

**Table 5.7: Yield components (weight per cob, diameter, length) of three maize varieties under four soil amendments in the CSZ and SDFZ in the minor season**

| Treatments | Weight per cob (g) | | Cob diameter (cm) | | Cob length (cm) | |
|---|---|---|---|---|---|---|
| **Varieties** | CSZ | SDFZ | CSZ | SDFZ | CSZ | SDFZ |
| Ahomatea | 132.0 | 147.9 | 3.33 | 3.49 | 13.0 | 14.5 |
| Obatanpa | 178.6 | 188.7 | 4.04 | 4.19 | 13.9 | 14.8 |
| Omankwa | 182.2 | 190.9 | 4.11 | 4.29 | 14.1 | 15.2 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 8.00 | 8.00 | 0.094 | 0.094 | 0.25 | 0.25 |
| **Soil amendments** | | | | | | |
| Fert + manure | 219.6 | 234.2 | 4.30 | 4.35 | 15.2 | 16.4 |
| Fertilizer | 211.5 | 225.3 | 4.14 | 4.30 | 15.0 | 15.9 |
| Manure | 194.0 | 210.7 | 3.87 | 4.12 | 14.5 | 15.3 |
| Res manure | 151.1 | 158.4 | 3.80 | 3.94 | 13.7 | 14.7 |
| Res fert + manure | 150.3 | 147.6 | 3.68 | 3.82 | 13.0 | 14.4 |
| Res fertilizer | 129.2 | 141.7 | 3.61 | 3.75 | 12.4 | 14.0 |
| Control | 107.9 | 112.8 | 3.38 | 3.65 | 11.7 | 13.0 |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Tukey (5%) | 10.52 | 10.52 | 0.13 | 0.13 | 0.51 | 0.51 |

Source: Field data, Marfo-Ahenkora (2018)

Obatanpa and Omankwa had better cob size (cob diameter and cob length) and significantly ($P < 0.001$) bigger weight per cob than Ahomatea in both locations. Irrespective of the maize variety used, the use of fertilizer + manure or sole fertilizer resulted in better cob weight, cob diameter and cob length in both locations (Table 5.7).

### *Mean 1000 grain weight (g)*

1000 grain weight was significantly ($P < 0.014$) influenced by the interaction between variety and soil amendments in both locations. Growing Obatanpa or Omankwa with 50% fertilizer + 50% goat manure or sole fertilizer, resulted in a similar and highest 1000 grain weight in both locations.

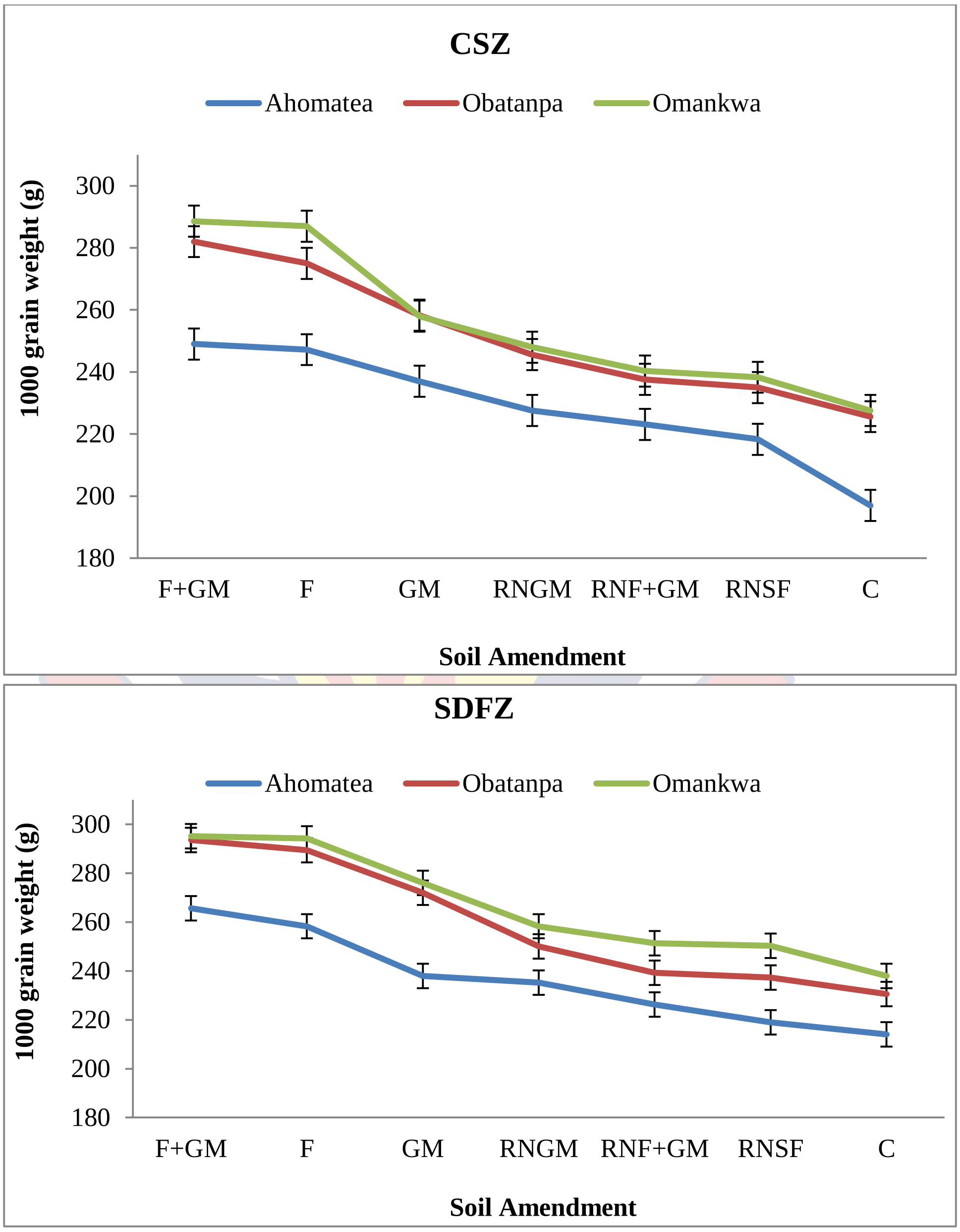


**Figure 5.1: 1000 grain weight of three maize varieties under different soil amendments in the CSZ and SDFZ for 2017 minor season.** F + GM= 50% F + 50% GM; F= Fertilizer; GM = Goat Manure; RNGM = Residual nutrients goat manure; RNF+GM = Residual nutrients fertilizer + Goat Manure; RNSF = Residual nutrient sole fertilizer; C= Control.

Growing Ahomatea with 50% fertilizer + 50% goat manure or sole fertilizer resulted in significantly ($P < 0.014$) lower 1000 grain weight in both locations. 1000 grain weight of plants on soil amendment such as residual goat manure, residual fertilizer + goat manure and residual sole fertilizer was significantly ($P < 0.001$) higher than 1000 grain weight of plants on the control plots irrespective of the location (Figure 5.1). Generally, the 1000 grain weight followed a trend and was in the order; fertilizer + manure > sole fertilizer > sole manure > residual manure > residual fertilizer + manure > residual fertilizer > control. Omankwa had higher 1000 grain weight compared to Obatanpa and Ahomatea in both AEZs.

***Mean grain yields (kg ha$^{-1}$)***

Maize grain yield followed a similar trend as the 1000 grain weight with significant ($P < 0.001$) interaction between variety and soil amendments in both locations. Growing Obatanpa or Omankwa with 50% fertilizer + 50% goat manure or fertilizer only, resulted in a similar and highest grain yield in both locations even though plants on the fertilizer + manure treatment had slightly higher yields than those on the sole fertilizer treatments. Planting Ahomatea with 50% fertilizer + 50% goat manure or fertilizer only resulted in significantly ($P < 0.001$) lower grain yield in both locations compared to that of Obatanpa and Omankwa. Ahomatea on control plots had the lowest grain yield. Grain yields of plants on residual soil amendments such as residual goat manure, residual fertilizer and residual fertilizer + goat manure were significantly ($P < 0.001$) higher than grain yields from the control plots irrespective of the variety and location.

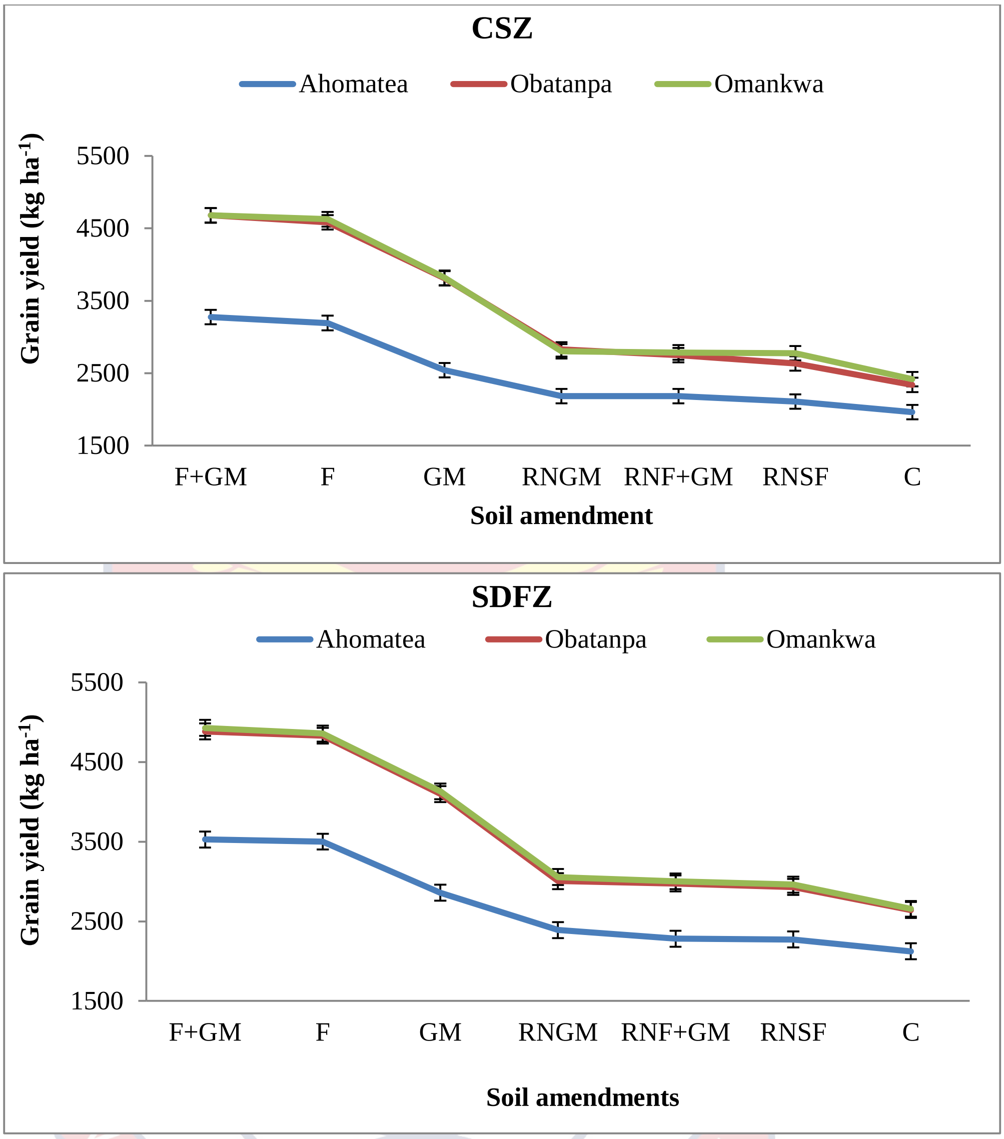


**Figure 5.2**: **Mean grain yield (kg ha$^{-1}$) of three maize varieties under different soil amendments in the Coastal savannah (CSZ) and Semi deciduous forest zones (SDFZ).** F + GM= 50% F + 50% GM; F= Fertilizer; GM = Goat Manure; RNGM = Residual nutrients goat manure; RNF+GM = Residual nutrients fertilizer + Goat Manure; RNSF = Residual nutrient sole fertilizer; C= Control. *Error bars represent the SED of soil amendments.*

Among plants on the residual nutrients, plants on residual manure had the highest grain yields irrespective of the variety and location (Fig 5.2). Generally, the grain yield followed a trend and was in the order; fertilizer + manure > sole fertilizer > sole manure > residual manure > residual fertilizer +

manure > residual fertilizer > control. Omankwa had significantly ($P < 0.001$) higher grain yield than the other varieties irrespective of the location. Grain yield of plants in the SDFZ was significantly ($P < 0.001$) higher than those in the CSZ.

Grain yields of the treatment combinations and their percentage yield increases over plants on the control plots have been presented in Table 5.8. There were considerable percentage yield increases of maize on all the amended plots over the control in both AEZs. In the CSZ, percentage yield increases ranged from 29.6% to 100% across the maize varieties for all the applied nutrients. Plants on the residual nutrients however had lower percentage yield increases ranging from 7.4% to 20.9% over plants in the control plot. In the SDFZ, percentage yield increases ranged from 34.6% to 85.5% across the maize varieties for all the applied nutrients. Plants on the residual nutrients however had lower percentage yield increases ranging from 7.0% to 15.0% over plants in the control plot.

Generally, plants on the fertilizer + manure plots had the highest percentage increase in yields over plants on the control plots for all the varieties. Plants on the residual nutrient plots however had the lowest percentage yield increases over the control plots with plants on the residual manure plots having the highest percentage increase among the residual nutrients for all the varieties.

**Table 5.8: Grain yield of maize under different soil amendments and percentage yield increases over plants on control plots in the SDFZ and CSZ**

| Treatment | Grain yield (kg ha$^{-1}$) | | Increase in yield over control plot (%) | |
|---|---|---|---|---|
| | CSZ | SDFZ | CSZ | SDFZ |
| Omankwa fertilizer +manure | 4681.0 | 4928.0 | 93.7 | 85.5 |
| Omankwa sole fertilizer | 4625.7 | 4856.6 | 91.4 | 82.8 |
| Omankwa sole manure | 3817.0 | 4130.8 | 57.9 | 55.5 |
| Omankwa Residual sole manure | 2801.3 | 3056.0 | 15.9 | 15.0 |
| Omankwa Residual fertilizer +manure | 2786.7 | 3001.8 | 15.3 | 13.0 |
| Omankwa Residual sole fertilizer | 2774.3 | 2960.3 | 14.8 | 11.4 |
| Omankwa control | 2417.0 | 2656.6 | - | - |
| Obatanpa fertilizer +manure | 4678.7 | 4883.5 | 100 | 84.9 |
| Obatanpa sole fertilizer | 4584.7 | 4830.2 | 96.6 | 82.9 |
| Obatanpa sole manure | 3809.0 | 4097.8 | 62.8 | 55.1 |
| Obatanpa Residual sole manure | 2827.3 | 3005.1 | 20.9 | 13.8 |
| Obatanpa Residual fertilizer +manure | 2747.7 | 2975.5 | 17.5 | 12.7 |
| Obatanpa Residual sole fertilizer | 2633.7 | 2931.2 | 12.6 | 11.0 |
| Obatanpa control | 2339.3 | 2641.4 | - | - |
| Ahomatea fertilizer +manure | 3275.7 | 3527.4 | 66.9 | 66.0 |
| Ahomatea sole fertilizer | 3193.3 | 3500.1 | 62.7 | 64.8 |
| Ahomatea sole manure | 2543.0 | 2859.1 | 29.6 | 34.6 |
| Ahomatea Residual sole manure | 2185.3 | 2390.2 | 11.3 | 12.5 |
| Ahomatea Residual fertilizer +manure | 2184.7 | 2281.8 | 11.3 | 7.4 |
| Ahomatea Residual sole fertilizer | 2107.3 | 2272.3 | 7.4 | 7.0 |
| Ahomatea control | 1962.7 | 2124.3 | - | - |

Source: Field data, Marfo-Ahenkora (2018)

### *Mean stover yield kg ha$^{-1}$*

Stover yields of maize was significantly (P <0.001) influenced by the interaction between variety and soil amendments in both locations. Obatanpa with 50% fertilizer + 50% goat manure or sole fertilizer had similar and highest stover yield whiles Omankwa and Ahomatea with 50% fertilizer + 50% goat manure or sole fertilizer resulted in a similar but significantly (P <0.001) lower stover yield than Obatanpa in the CSZ. In the SDFZ however, growing Obatanpa and Ahomatea with 50% fertilizer + 50% goat manure or sole fertilizer resulted in similar and highest stover yields. Even though Omankwa followed a similar trend, it had significantly (P <0.001) lower stover yields compared to Obatanpa and Ahomatea.

Soil amendment such as residual nutrient of goat manure, residual fertilizer + goat manure and residual sole fertilizer did not make much difference in stover yield compared to the control irrespective of the variety and location (Figure 5.3). Among the residual nutrient plots, plants on residual manure treated plots had the highest stover yield for all varieties and in both locations except for Obatanpa in the SDFZ where plants on residual fertilizer + goat manure had higher stover yields than that of the residual manure plots. All the varieties had the highest stover yields on the fertilizer + manure plots and the lowest yields on the control plots in both AEZs. Stover yields also followed a similar trend as grain yield and was in the order; fertilizer + manure > sole fertilizer > sole manure > residual manure > residual fertilizer + manure > residual fertilizer > control.

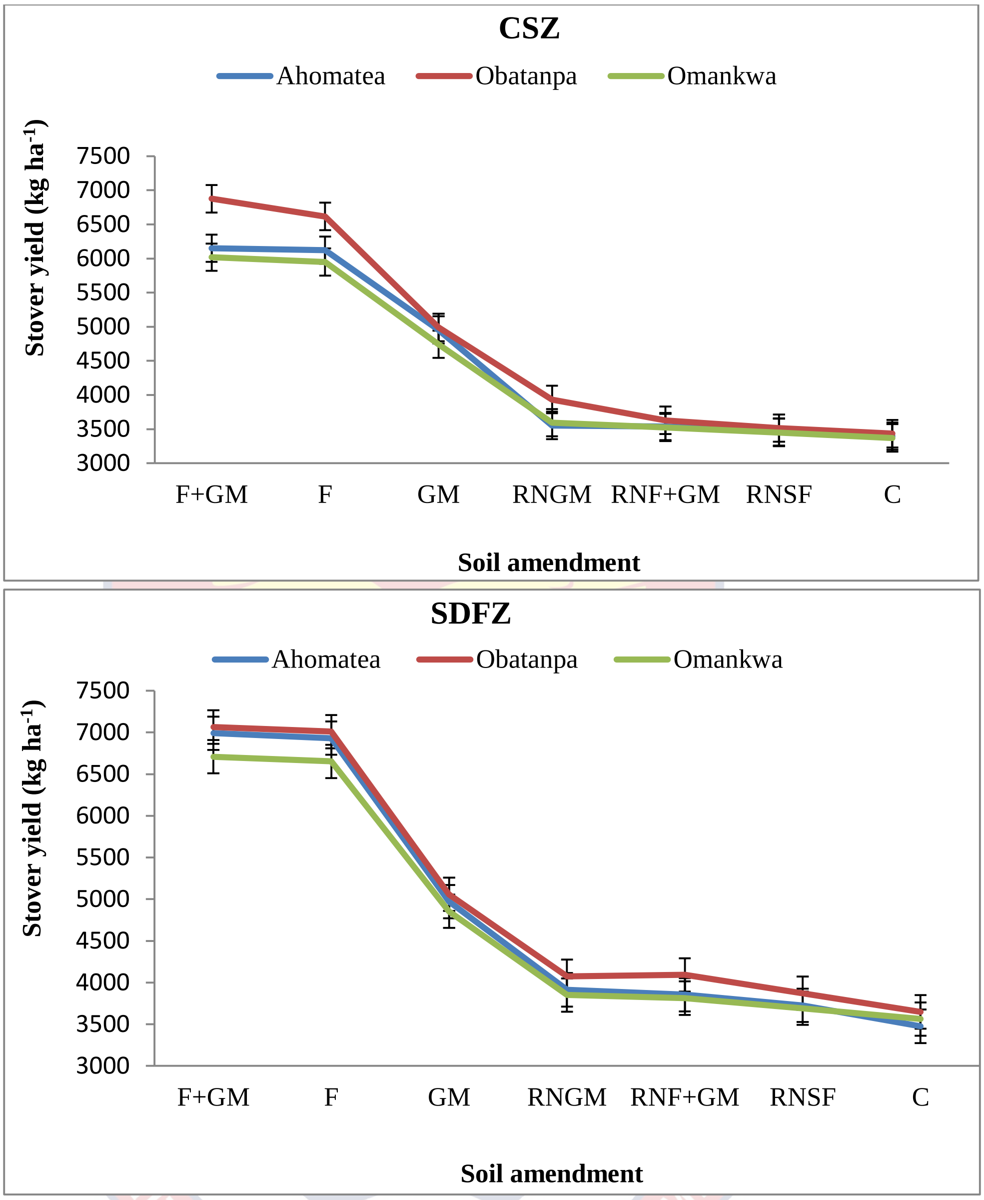


**Figure 5.3: Stover yield of three maize varieties under different soil amendments at CSZ and SDFZ in the minor season**

## 5.5. Discussion

### 5.5.1. Effect of application of soil amendments (inorganic fertilizer, goat manure and their combination) in the minor season on growth and yield of three maize varieties in the two AEZs of Ghana

*Growth*

Growth parameters such as plant height, stem girth and leaf area are ascribed to the genetic makeup of a particular variety. Within a variety however, these growth parameters can differ depending on the crops environment. Plant height is an important growth characteristic that is associated with the productive potential of a plant in relation to biomass and grain yield. Berchie et al. (2013) observed that plant height is among the most important biomass yield components of maize crop and that besides being a genetic trait, it is also a reflection of nutrient availability, management and favourable prevailing weather conditions. The observed results in this study where the soil amendments introduced generally improved growth and yield of all varieties as evidenced in the taller plants, bigger stem girth and larger leaf area produced by plants on plots with applied nutrients in the order of fertilizer + manure > sole fertilizer > sole manure compared to that of plants on the residual nutrients and the control (no amendment) agrees with findings by Farhad et al. (2013) and Choudhari & Channappagoudar (2014) that, application of manure as well as mineral fertilizer improves crop growth than not applying any amendment. Studies have shown that application of inorganic and or organic fertilizers increases plant growth mainly because they contain considerable quantities of plant nutrients, including micro nutrients which have high benefits for plant growth (Ibeawuchi et al ., 2006). Ahmad et al. (2001) also reported that plant height and leaf area of wheat increased significantly by combining organic and inorganic N fertilizers.

The shortest plant height, smallest stem girth and leaf area observed for all the varieties on plots which did not receive any soil amendment was perhaps due to the relatively low nutrient levels observed in the initial soil analysis. Low levels of nutrients particularly N in the soil will definitely result in relatively poor vegetative growth and subsequent poor yields considering the role N plays in plant nutrition.

***Yields***

The significant variations observed in maize yields in all the varieties were as a result of the different soil amendments applied. The significant interactions between variety and soil amendments for 1000 grain weight, grain and stover yield, suggests the possibility of selecting specific soil amendments for certain varieties. In this study however, all the varieties responded to the soil amendments in a similar trend. Among the varieties, the cob weight, diameter, length and number of kernels per cob was observed to be highest for Omankwa and this is what possibly led to the attainment of highest grain yield by Omankwa. This suggests a strong relationship between these yield components and grain yield. The observed lower grain yields from Ahomatea which is a local variety on all the soil amendments suggest that the yield potential of the local variety is relatively low and again, it is possible that the local varieties are less responsive to fertilizer application compared to improved varieties as alluded to by Sallah and Twumasi-Afriyie (1999).

Plants on the fertilizer + manure treatments which gave the highest yields (1000 grain weight, grain yield and stover yield) for all varieties used in the study in the minor season seems to suggest that integrated application of manure and inorganic fertilizer was beneficial over the use of inorganic fertilizer or manure alone in the minor season. It is possible that the first application of manure in the fertilizer + manure treatments in the major season, improved the organic matter content of the soil and so the second application of 50 % NPK in addition to the manure in the fertilizer + manure treatment in the minor season enhanced fertilizer utilisation hence the increased yields. Organic matter (OM) is known to improve fertilizer use efficiency according to Ker (1995) who reported that maize responds well to phosphate and nitrogen fertilizers, particularly where sufficient OM is also made available. Earlier studies demonstrate that use of manure could enhance efficiency of chemical fertilizers through synergistic effect and thereby increase maize yields (Mugwe et al., 2007; Shafi et al., 2012). Studies in SSA show that restoration of soil fertility through balanced fertilization and organic matter additions is necessary to achieve high crop productivity (Zingore 2011). This is because the combination of organic and inorganic fertilizer is known to contain considerable quantities of plant nutrients, including micro nutrients (Ibeawuchi et al., 2006). This is probably the reason for higher yields in plants on fertilizer + manure plots in this study compared to the other soil amendments.

Yield results recorded in this study indicated that combined application of goat manure and inorganic fertilizer could result in the reduction of the quantity of inorganic fertilizer used as well as manure applied without compromising maize yields as observed for the fertilizer + manure treatments. Sonko (2016) obtained similar results but cautioned that, the effectiveness of combining cattle manure with inorganic N also depends on the rate of manure application and the timing of N application.

### 5.5.2. Performance of three maize varieties on residual nutrients (residual fertilizer, residual manure, residual fertilizer +manure) in the minor season in two AEZs of Ghana.

The observed comparatively delayed number of days to all the phenological stages for plants on the residual nutrients and control plots was also reported by

Buah et al, (2009) who observed that fertilized plants produce silk 5 days earlier than those that were not fertilized and suggested that, applied N shortened the time from emergence to mid silk (50% silking). The residual nutrients in this study were probably not enough to hasten the phenological stages compared to plants with applied soil amendments.

The residual nutrients generally improved maize growth over those on the control plots (no amendments) suggesting that some nutrients from the first application (major season) might have been left in the soil which benefited the succeeding maize crop. Raramurthy and Shivashankar (1996) made similar observations and reported that, in corn, the residual effect of organic matter improved the plant height, stem girth, leaf area, and dry-matter production at different stages of crop growth over the control. The observation that growth and yield attributes such as plant height, stem girth, leaf area and grain yield were highest for plants on residual manure plots in the order residual manure > residual fertilizer + manure > residual fertilizer, implied that perhaps manure applied in the first season left more residues compared to the other residual nutrients plots which might have resulted in the higher yields observed for grain yield. Cooke (1970) cited by Quansah (2010), reported that farmyard manure and fertilizers from previous applications, leaves residues of nitrogen, phosphorus and potassium in the soil that benefit following crops and that the residues of inorganic nitrogen fertilizers usually last only for a season. Quansah (2010) however observed that plants on residual inorganic fertilizer had higher yields than plants on the combined (manure + fertilizer) residual nutrients plots.

The effect of applied manure on grain yield was more evident in the minor season probably because of better mineralisation of manure from the first application (major season) and the nutrients being made available to the plants in the minor season. Ramamurthy and Shivashankar, (1996) and Eghball, (2002) made similar observations and reported that, residual effects of manure or compost application can maintain crop yield level for several years after manure or compost application ceases since only a fraction of the N and other nutrients in manure or compost become plant available in the first year after application.

The observed low percentage yield increases of plants on residual nutrients compared to their counterparts which received amendments again in the minor season was indicative of reduced nutrients in the soil. Quansah (2010) similarly observed 50% lower yields in residual plots compared to their major season yields. In this study, plants on the residual plots had yields which were generally lower even though grain and stover yields from the residual plots were significantly higher than that of the control plots indicating that the residual nutrients from both manure and mineral fertilizer might have left some residues that benefitted the succeeding crop as was also observed by Sharma et al. (1987) and Quansah (2010). However, the reduction in yield of maize in the residual plots was an indication that the residual nutrients were probably not sufficient for the normal growth and yield of the succeeding maize crop. The generally higher growth and yield parameters observed in plants in the SDFZ than the CSZ may probably be due to higher rainfall amounts received in the SDFZ compared to the CSZ.

## 5.6. Chapter summary

The study conducted in the CSZ and SDFZ in the Central and Eastern regions of Ghana respectively in the minor cropping season revealed that:

- Combined application of goat manure and inorganic fertilizer (50% inorganic fertilizer + 50% goat manure) resulted in yields (1000 grain weight, grain and stover) which were higher than that of the sole application of manure or inorganic fertilizer in the minor season.
- Yield results (1000 grain weight, grain and stover) recorded in the minor season indicated that combined application of goat manure and inorganic fertilizer resulted in the reduction of the quantities of inorganic fertilizer and manure applied without compromising maize yields.
- Application of goat manure and inorganic fertilizer at economically viable rates (47.5 kg N ha$^{-1}$, 18.8 kg P ha$^{-1}$ , 18.8 kg K ha$^{-1}$ + 2.5 t ha$^{-1}$ goat manure) reported in this study can significantly contribute to sustained maize production at the smallholder level.
- Plants on the control plots obtained the lowest yields for Omankwa, Obatanpa and Ahomatea.
- Grain yields from the residual sole manure plots were higher compared to yields obtained by the residual combined treatments and the residual sole inorganic fertilizer
- For all varieties, plants on plots with residual nutrients recorded yields (1000 grain weight, grain and stover) which were relatively lower than what was obtained from plots with added nutrients.
- Grain and stover yields from plants on plots with residual nutrients were relatively higher than that on the control plots. This indicates that the residual nutrients from both the goat manure and/or mineral fertilizer benefitted the subsequent maize crop to some extent in terms of growth and yield.

- Obatanpa and Omankwa which were both OPVs recorded higher yields over the local variety (Ahomatea) under all the different soil amendments and in both agro–ecological zones.
- Omankwa had the highest grain yield and 1000 grain weight among the varieties studied in both AEZs.
- The growth and yield parameters were generally higher in the SDFZ than in the CSZ

# CHAPTER SIX

# EFFECT OF CHANGES IN MAIZE VARIETY AND SOIL AMENDMENTS ON MAIZE PRODUCTION PROFITS IN TWO AGRO-ECOLOGICAL ZONES OF GHANA – A PARTIAL BUDGETING APPROACH

## 6.1. Introduction

Maize is the most important cereal crop in most parts of West Africa accounting for over 50% of the total cereal production in Ghana with annual yields reported to be growing around 1.1% (Fosu et al., 2004; IFPRI, 2014). Due to the importance of maize in Ghana, the entire agricultural sector would benefit from increasing maize yield.

For farmers to realize economic benefits from their farms, interventions such as the use of improved seeds, inorganic fertilizers, organic amendments and improved agronomic practices have to be made. Buah et al. (2009) reported that, most farmers in the Guinea savannah zone of Ghana have low income and so technical packages to increase and sustain agricultural production must be affordable, profitable and applicable to ensure their acceptability. The profitability of using options such as mineral fertilizer and manure must be investigated in time and space to explore their feasibility, and sustainability. Even though smallholder resource poor farmers in Ghana appreciate the use of inorganic fertilizers, Wiredu et al. (2010) reported that, high fertilizer prices coupled with low produce prices of farm commodities are challenges that hinder the appropriate rate of application and use of inorganic fertilizers in Ghana.

Scientists more often than not, consider only biological advantages of technological innovations which may not be economically feasible. Farmers are concerned with the costs and benefits of particular technologies and will consider the risks involved in adopting new/improved technologies. The economic analysis of agronomic data helps researchers to look at the results from the farmers' viewpoint, to decide which treatments merit further investigation, and which recommendations can be made to enhance selection of right combination of resources by farmers (CIMMYT, 1988; Berchie et al., 2013). Detailed information on cost and return is therefore a prerequisite for adoption of technical innovation by farmers (Das et al., 2010).

Ragasa et al. (2013) reported that research is needed to look more closely at the profitability of maize production with and without fertilizer as well as low-input soil fertility management practices.

## 6.2 Objective

The primary objective of the study was to carry out economic analysis to assess the change in profitability of using inorganic fertilizer and/ or goat manure as soil amendments on three maize varieties. The specific objectives include:

1. to compute and compare increase in net benefit arising from changes in maize variety and soil amendments in the major season in the Semi-deciduous forest and Coastal savannah zones
2. to assess and compare the change in net benefit from re-application of soil amendments to that with no application of soil amendments (residual nutrients) in the minor season in the two zones.

## 6.3 Methodology

Partial budgeting was used to assess the effect of maize variety and soil amendment on profits in maize production systems in the Semi-deciduous forest and Coastal savannah zones. Partial budgeting is a method for computing the anticipated change in profit from a proposed change in a production system. It compares the profitability of one alternative to another. It uses information on changes in cost and revenues arising from the implementation of a recommended alternative. Cost and revenues that are not affected by the recommended change do not matter. Such cost and revenues are identified by examining 1. additional costs that arise. 2. current cost which are reduced or eliminated. 3. additional revenue that are obtained. 4. current revenue that is foregone (Kay and Edwards, 1994). First, physical changes are identified and then economic value put on them. Thus, a typical format for partial budget analysis is to compare gross benefits and costs for each alternative while considering only costs that vary with the different alternatives that are considered (CIMMYT, 1988).

The gross benefit is computed from average yield and price per unit of produce. Adjustment are made to yield obtained from on-farm experimental fields since it is thought that farmers using same technologies will obtain yields lower than those obtained by researchers. The adjusted yield is valued at the field price which is the value of one kilogramme of the crop to the farmer at the farm gate. The total costs that vary for each alternative is the sum of the individual cost that vary. Net benefit is the difference between gross benefit and total variable cost.

In the maize production system considered, the current practice (alternative) does not use improved seeds nor soil amendments. The new alternative involves the introduction of improved seeds, and soil amendments like chemical fertilizer and manure. Adoption of the new alternative leads to additional cost arising from the use of improved seeds, fertilizer and manure.

Additionally, cost is also incurred in acquiring labour to apply fertilizer and manure (Appendix D). Land rental, land preparation, planting, hand weeding and harvesting practices remain the same for all fields and is assumed to cost the same regardless of seed variety and soil amendment alternatives. In the minor cropping season, the total variable cost was the same for sole fertilizer, sole manure, fertilizer + manure and the control plots as in the major season. The residual nutrients (residual fertilizer, residual manure, residual fertilizer +manure) however had only the cost of seed as the total variable cost. Furthermore, the researcher judges that farmer's yields will be five percent (5%) lower than those obtained by researchers in on farm experimentations. Computations of yields (Tables 4.10 for major season & 5.8 minor season) , input use, costs and benefits are done on per hectare basis.

### 6.3.1 Economic benefit analysis for the three maize varieties under different soil amendments in the major and minor cropping season

The total variable cost (TVC) for each variety with their soil amendments has been illustrated in Table 6.1. Obatanpa and Omankwa had the same total variable cost for all the soil amendments with values that were relatively higher than that of the Ahomatea (local variety). The total variable cost was highest in the sole fertilizer treatment for all the varieties and in the order of: sole fertilizer > fertilizer + manure > sole manure > control. All cost elements were calculated per hectare in Ghana cedis (GH¢).

The calculations of the gross and net benefits for the maize varieties under the different soil amendments in the two AEZs are shown in Tables 6.2 & 6.3 for major season and Tables 6. 5 to 6.7 for the minor season.

**Table 6.1: Total variable costs for the three maize varieties and different soil amendments in the major season**

| Operation/Input Cost | Ahomatea | | | | Obatanpa | | | | Omankwa | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | GM | F + GM | C | F | GM | F + GM | C | F | GM | F + GM | C |
| Cost of seed (GH¢) | 30.00 | 30.00 | 30.00 | 30.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Cost of fertilizer (GH¢) | 922.50 | 0.00 | 461.25 | 0.00 | 922.50 | 0.00 | 461.25 | 0.00 | 922.50 | 0.00 | 461.25 | 0.00 |
| Cost of manure (GH¢) | 0.00 | 250.00 | 125.00 | 0.00 | 0.00 | 250.00 | 125.00 | 0.00 | 0.00 | 250.00 | 125.00 | 0.00 |
| Cost of labour for fertilizer application (GH¢) | 111.00 | 0.00 | 55.50 | 0.00 | 111.00 | 0.00 | 55.50 | 0.00 | 111.00 | 0.00 | 55.50 | 0.00 |
| Cost of labour for manure application (GH¢) | 0.00 | 111.00 | 55.50 | 0.00 | 0.00 | 111.00 | 55.50 | 0.00 | 0.00 | 111.00 | 55.50 | 0.00 |
| Total variable cost (GH¢) | 1,063.50 | 391.00 | 727.25 | 30.00 | 1,133.50 | 461.00 | 797.25 | 100.00 | 1,133.50 | 461.00 | 797.25 | 100.00 |

Source: Field data, Marfo-Ahenkora (2018)

Seed rate was calculated at 20 kg ha$^{-1}$ and GH¢ 5.00 per kg for Obatanpa and Omankwa and GH¢ 1.50 per kg for the local variety; Cost of fertilizer includes fertilizer (cost of 50 kg NPK- GH120.00, cost of Urea 50 kg -GH 115.00) and transportation cost per hectare. Cost of manure was made up of transportation and manure collection fees per hectare (manure was freely available in the community). F= fertilizer; GM = Goat Manure; F + GM= 50% Fertiliser + 50% Goat Manure; C= Control (Farmer practice).

**Table 6.2: Mean grain yield in the major season for the Ahomatea (local variety), Obatanpa, Omankwa and their economic analysis for variable cost, gross and net benefits in the SDFZ**

| Operation/Input Cost | Ahomatea | | | | Obatanpa | | | | Omankwa | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | GM | F + GM | C | F | GM | F + GM | C | F | GM | F + GM | C |
| Average yield | 3489.7 | 2856.7 | 3350.7 | 2135.1 | 4794 | 3583 | 4700.0 | 2668.3 | 4828.3 | 3802.3 | 4731.3 | 2681 |
| Adjusted yield (by 5%) | 3315.2 | 2713.9 | 3183.2 | 2028.3 | 4554.3 | 3403.9 | 4465.0 | 2534.9 | 4586.9 | 3612.2 | 4494.7 | 2547.0 |
| Gross benefits (price = (GH¢1.3/kg) | 4,309.78 | 3,528.02 | 4,138.11 | 2,636.85 | 5,920.59 | 4,425.01 | 5,804.50 | 3,295.35 | 5,962.95 | 4,695.84 | 5843.16 | 3,311.04 |
| Cost of seed | 30.00 | 30.00 | 30.00 | 30.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Cost of fertilizer | 922.50 | - | 461.25 | - | 922.50 | - | 461.25 | - | 922.50 | - | 461.25 | - |
| Cost of manure | - | 250.00 | 125.00 | - | - | 250.00 | 125.00 | - | - | 250.00 | 125.00 | - |
| Cost of labour to apply fertilizer | 111.00 | - | 55.50 | - | 111.00 | - | 55.50 | - | 111.00 | - | 55.50 | - |
| Cost of labour to apply manure | - | 111.00 | 55.50 | - | - | 111.00 | 55.50 | - | - | 111.00 | 55.50 | - |
| Total variable cost (GH¢) | 1,063.50 | 391.00 | 727.25 | 30.00 | 1,133.50 | 461.00 | 797.25 | 100.00 | 1,133.50 | 461.00 | 797.25 | 100.00 |
| Net benefit (GH¢) | 3,246.28 | 3,137.02 | 3,410.86 | 2,606.85 | 4,787.09 | 3,964.01 | 5,007.25 | 3,195.35 | 4,829.45 | 4,234.84 | 5,045.91 | 3,211.04 |

Source: Field data, Marfo-Ahenkora (2018)

Seed rate was calculated at 20 kg ha$^{-1}$ and GH¢ 5.00 per kg for Obatanpa and Omankwa and GH¢ 1.50 per kg for the local variety; Cost of fertilizer was made up of fertilizer (cost of 50 kg NPK- GH120.00, cost of Urea 50 kg -GH 115.00) and transportation cost per hectare. Cost of manure was made up of transportation and manure collection fees per hectare (manure was freely available in the community). F= fertilizer; GM = Goat Manure; F + GM= 50% Fertiliser + 50% Goat Manure; C= Control (Farmer practice).

**Table 6.3: Mean grain yield in the major season for the Ahomatea (local variety), Obatanpa, Omankwa and their economic analysis for variable cost, gross and net benefits in the CSZ.**

| Operation/Input Cost | Ahomatea | | | | Obatanpa | | | | Omankwa | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | GM | F + GM | C | F | GM | F +G M | C | F | GM | F + GM | C |
| Average yield | 3184.3 | 2400 | 3175.7 | 1975.3 | 4564 | 3399 | 4431.7 | 2451 | 4578 | 3514 | 4474 | 2498 |
| Adjusted yield (by 5%) | 3025.1 | 2280.0 | 3016.9 | 1876.5 | 4335.8 | 3229.1 | 4210.1 | 2328.5 | 4349.1 | 3338.3 | 4250.3 | 2373.1 |
| Gross field benefits (price = (GH¢1.3/kg) | 3,932.61 | 2,964.00 | 3,921.99 | 2,439.50 | 5,636.54 | 4,197.77 | 5,473.15 | 3,026.99 | 5,653.83 | 4,339.79 | 5,525.39 | 3,085.03 |
| Cost of seed | 30.00 | 30.00 | 30.00 | 30.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Cost of fertilizer | 922.50 | - | 461.25 | - | 922.50 | - | 461.25 | - | 922.50 | - | 461.25 | - |
| cost of manure | - | 250.00 | 125.00 | - | - | 250.00 | 125.00 | - | - | 250.00 | 125.00 | - |
| Cost of labour to apply fertilizer | 111.00 | - | 55.50 | - | 111.00 | - | 55.50 | - | 111.00 | - | 55.50 | - |
| Cost of labour to apply manure | - | 111.00 | 55.50 | - | - | 111.00 | 55.50 | - | - | 111.00 | 55.50 | - |
| Total variable cost (GH¢) | 1,063.50 | 391.00 | 727.25 | 30.00 | 1,133.50 | 461.00 | 797.25 | 100.00 | 1,133.50 | 461.00 | 797.25 | 100.00 |
| Net benefit (GH¢) | 2,869.11 | 2,573.00 | 3,194.74 | 2,409.50 | 4,503.04 | 3,736.77 | 4,675.90 | 2,926.99 | 4,520.33 | 3,878.79 | 4,728.14 | 2,985.03 |

Source: Field data, Marfo-Ahenkora (2018)

Seed rate was calculated at 20 kg ha$^{-1}$ and GH¢ 5.00 per kg for Obatanpa and Omankwa and GH¢ 1.50 per kg for the local variety; Cost of fertilizer includes fertilizer (cost of 50 kg NPK- GH120.00, cost of Urea 50 kg -GH 115.00) and transportation cost per hectare. Cost of manure was made up of transportation and manure collection fees per hectare (manure was freely available in the community). F= fertilizer; GM = Goat Manure; F + GM= 50% Fertiliser + 50% Goat Manure; C= Control (Farmer practice).

## 6.4 Results

### 6.4.1 Results of economic benefit analysis for the three maize varieties under different soil amendments in the major cropping season

Net benefit per hectare in the major season has been presented in Table 6.2 for the SDFZ and Table 6.3 for CSZ. The partial budgeting showed that the lowest net benefit was GH¢ 2,606.85 and GH¢ 2,409.50 for the local variety (Ahomatea) on the control plots in the SDFZ and CSZ respectively in the major season). The highest net benefit was recorded by Omankwa (GH¢ 5,045.91) which was followed by Obatanpa (GH¢ 5,007.25) all on the fertilizer + manure treatments in the SDFZ. Again in the CSZ, Omankwa recorded the highest net benefit (GH¢ 4,728.14) followed by Obatanpa (GH¢ 4,675.90) also on the fertilizer + manure treated plots (Table 6.4). In the major cropping season, Omankwa variety recorded the highest net benefit under all the soil amendments in both AEZs. In the major cropping season, the general trend observed was that, all the varieties recorded their highest net benefit for plants on the fertilizer + manure treated plots and the other treatments followed in the order of ; fertilizer + manure > sole fertilizer > sole manure > control in both AEZs (Tables 6.4). Even though in the major cropping season grain yields were highest in the sole fertilizer treated plot for all the varieties in both SDFZ and CSZ (Table 4.10), the economic analysis revealed that the fertilizer + manure treatments rather gave the highest net benefit for all varieties.

**Table 6.4: Summary of net benefits (GH ¢ ha$^{-1}$) for the three maize varieties under different soil amendments in the major season**

| Maize Varieties | Net benefits of maize per hectare (GH ¢) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Coastal savannah | | | | Semi deciduous forest | | | |
| | F+GM | F | GM | C | F+GM | F | GM | C |
| Ahomatea | 3,194.74 | 2,869.11 | 2,573.00 | 2,409.50 | 3,410.86 | 3,246.28 | 3,137.02 | 2,606.85 |
| Obatanpa | 4,675.90 | 4,503.04 | 3,736.77 | 2926.99 | 5,007.25 | 4,787.09 | 3,964.01 | 3,195.35 |
| Omankwa | 4,728.14 | 4,520.33 | 3,878.79 | 2,985.03 | 5,045.91 | 4829.45 | 4,234.84 | 3,211.04 |

Source: Field data, Marfo-Ahenkora (2018)

F= fertilizer; GM = Goat Manure; F + GM= 50% Fertiliser + 50% Goat Manure; C= Control

### 6.4.2 Results on economic benefit analysis for the three maize varieties under different soil amendments in the minor cropping season

Net benefits per hectare in the minor season have been presented in Tables 6.5 to 6.7 for both the SDFZ and CSZ. The partial budgeting showed that, generally Omankwa recorded higher net benefits than Ahomatea and Obatanpa for all the soil amendments in both AEZs. The highest net benefit was given by Omankwa on plots amended with fertilizer + manure in both the SDFZ (GH¢ 5,288.83) and the CSZ (GH¢ 4,983.79) whiles Ahomatea on the control plots recorded the lowest net benefit of GH¢ 2,593.51 and GH¢ 2,393.93 in the SDFZ and CSZ respectively. Obatanpa had higher net benefits than Ahomatea for all the soil amendments. Ahomatea had the lowest net benefit among the varieties for all the soil amendments in both the SDFZ and CSZ. For all the varieties, plants on the control plots recorded the lowest net benefits in both AEZs.

**Table 6.5: Partial budget analysis for Ahomatea under different soil amendments in the SDFZ and CSZ in the minor season**

| Operation/Input | Semi deciduous forest zone (SDFZ) | | | | | | | Coastal savannah zone (CSZ) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost | Fert+Man | Fertilizer | Manure | RNGM | RNF+GM | RNSF | Control | Fert+Man | Fertilizer | Manure | RNGM | RNF+GM | RNSF | Control |
| Average Yield (kg ha$^{-1}$) | 3527.4 | 3500.1 | 2859.1 | 2390.2 | 2281.8 | 2272.3 | 2124.3 | 3275.7 | 3193.3 | 2543 | 2185.3 | 2184.7 | 2107.3 | 1962.7 |
| Adjusted yield (by 5%) | 3351.0 | 3325.1 | 2716.1 | 2270.7 | 2167.7 | 2158.7 | 2018.1 | 3111.9 | 3033.6 | 2415.9 | 2076.0 | 2075.5 | 2001.9 | 1864.6 |
| Gross field benefits (price =GH¢1.3/kg) | 4,356.34 | 4,322.62 | 3,530.99 | 2,951.90 | 2,818.02 | 2,806.29 | 2,623.51 | 4,045.49 | 3,943.73 | 3,140.61 | 2,698.85 | 2,698.10 | 2,602.52 | 2,423.93 |
| Cost of seed(GH¢) | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 |
| Cost of fertilizer(GH¢) | 461.25 | 922.50 | - | - | - | - | - | 461.25 | 922.50 | - | - | - | - | - |
| Cost of manure (GH¢) | 125.00 | - | 250.00 | - | - | - | - | 125.00 | - | 250.00 | - | - | - | - |
| Cost of labour to apply fertilizer (GH¢) | 55.50 | 111.00 | - | - | - | - | - | 55.50 | 111.00 | - | - | - | - | - |
| Cost of labour to apply manure (GH¢) | 55.50 | - | 111.00 | - | - | - | - | 55.50 | - | 111.00 | - | - | - | - |
| Total variable costs (GH¢) | 727.25 | 1,063.50 | 391.00 | 30.00 | 30.00 | 30.00 | 30.00 | 727.25 | 1,063.50 | 391.00 | 30.00 | 30.00 | 30.00 | 30.00 |
| Net benefit (GH¢) | 3,629.09 | 3,259.12 | 3,139.99 | 2,921.90 | 2,788.02 | 2,776.29 | 2,593.51 | 3,318.24 | 2,880.23 | 2,749.61 | 2,668.85 | 2,668.10 | 2,572.52 | 2,393.93 |

Source: Field data, Marfo-Ahenkora (2018)

Seed rate was calculated at 20 kg ha$^{-1}$ and GH¢ 1.50 per kg for the local variety; Cost of fertilizer includes fertilizer (cost of 50 kg NPK- GH120.00, cost of Urea 50 kg -GH 115.00) and transportation cost per hectare. Cost of manure was made up of transportation and manure collection fees per hectare (manure was freely available in the community).; Fert + man = 50% Fertiliser + 50% Goat Manure; Control = Farmer practice; RNSF = Residual nutrient sole fertilizer; RNGM = Residual nutrients goat manure; RNF+GM = Residual nutrients fertilizer + goat manure

**Table 6.6: Partial budget analysis for Obatanpa under different soil amendments in the SDFZ and CSZ in the minor season**

| Operation/Input Cost | Semi deciduous forest zone (SDFZ) | | | | | | | Coastal savannah zone (CSZ) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fert+man | Fertilizer | Manure | RNGM | RNF+GM | RNSF | Control | Fert+Man | Fertilizer | Manure | RNGM | RNF+GM | RNSF | Control |
| Average Yield (kg ha$^{-1}$) | 4883.5 | 4830.2 | 4097.8 | 3005.1 | 2975.5 | 2931.2 | 2641.4 | 4678.7 | 4584.7 | 3809 | 2827.3 | 2747.7 | 2633.7 | 2339.3 |
| Adjusted yield (by 5%) | 4639.3 | 4588.7 | 3892.9 | 2854.8 | 2826.7 | 2784.6 | 2509.3 | 4444.8 | 4355.5 | 3618.6 | 2685.9 | 2610.3 | 2502.0 | 2222.3 |
| Gross field benefits (price =GH¢1.3/kg) | 6,031.12 | 5,965.30 | 5,060.8 | 3,711.1 | 3,674.74 | 3,620.03 | 3,262.13 | 5,778.19 | 5,662.10 | 4,704.12 | 3,491.72 | 3,393.41 | 3,252.62 | 2,889.04 |
| Cost of seed(GH¢) | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Cost of fertilizer(GH¢) | 461.25 | 922.50 | - | - | - | - | - | 461.25 | 922.50 | - | - | - | - | - |
| Cost of manure (GH¢) | 125.00 | - | 250.00 | - | - | - | - | 125.00 | - | 250.00 | - | - | - | - |
| Cost of labour to apply fertilizer (GH¢) | 55.50 | 111.00 | - | - | - | - | - | 55.50 | 111.00 | - | - | - | - | - |
| Cost of labour to apply manure (GH¢) | 55.50 | - | 111.00 | - | - | - | - | 55.50 | - | 111.00 | - | - | - | - |
| Total variable costs (GH¢) | 797.25 | 1,133.50 | 461.00 | 100.00 | 100.00 | 100.00 | 100.00 | 797.25 | 1,133.50 | 461.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Net benefit (GH¢) | 5,233.87 | 4,831.80 | 4,599.78 | 3,672.55 | 3,611.30 | 3,520.03 | 3,162.13 | 4,980.94 | 4,528.60.24 | 4,243.12 | 3,391.72 | 3,293.41 | 3,152.62 | 2,789.04 |

Source: Field data, Marfo-Ahenkora (2018)

Seed rate was calculated at 20 kg ha$^{-1}$ and GH¢ 1.50 per kg for the local variety; Cost of fertilizer includes fertilizer (cost of 50 kg NPK- GH120.00, cost of Urea 50 kg -GH 115.00) and transportation cost per hectare. Cost of manure was made up of transportation and manure collection fees per hectare (manure was freely available in the community).; Fert + man = 50% Fertiliser + 50% Goat Manure; Control = Farmer practice; RNSF = Residual nutrient sole fertilizer; RNGM = Residual nutrients goat manure; RNF+GM = Residual nutrients fertilizer + goat manure

**Table 6.7: Partial budget analysis for Omankwa under different soil amendments in the SDFZ and CSZ in the minor season**

| Operation/Input Cost | Semi deciduous forest zone (SDFZ) | | | | | | | Coastal savannah zone (CSZ) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fert+Man | Fertilizer | Manure | RNGM | RNF+GM | RNSF | Control | Fert+Man | Fertilizer | Manure | RNGM | RNF+GM | RNSF | Control |
| Average Yield (kg ha$^{-1}$) | 4928.0 | 4856.6 | 4130.8 | 3056.0 | 3001.8 | 2960.3 | 2656.6 | 4681 | 4625.7 | 3817 | 2801.3 | 2786.7 | 2774.3 | 2417 |
| Adjusted yield (by 5%) | 4681.6 | 4613.8 | 3924.3 | 2854.8 | 2851.7 | 2812.3 | 2523.8 | 4447.0 | 4394.4 | 3626.2 | 2661.2 | 2647.4 | 2635.6 | 2296.2 |
| Gross field benefits (price =GH¢1.3/kg) | 6,086.08 | 5,997.90 | 5,101.54 | 3,774.16 | 3,707.2 | 3,655.97 | 3,280.90 | 5,781.04 | 5,712.74 | 4,714.00 | 3,459.61 | 3,441.57 | 3,426.26 | 2,985.00 |
| Cost of seed (GH¢) | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Cost of fertilizer (GH¢) | 461.25 | 922.50 | - | - | - | - | - | 461.25 | 922.50 | - | - | - | - | - |
| Cost of manure (GH¢) | 125.00 | - | 250.00 | - | - | - | - | 125.00 | - | 250.00 | - | - | - | - |
| Cost of labour to apply fertilizer (GH¢) | 55.50 | 111.00 | - | - | - | - | - | 55.50 | 111.00 | - | - | - | - | - |
| Cost of labour to apply manure (GH¢) | 55.50 | - | 111.00 | - | - | - | - | 55.50 | - | 111.00 | - | - | - | - |
| Total variable costs (GH¢) | 797.25 | 1,133.50 | 461.00 | 100.00 | 100.00 | 100.00 | 100.00 | 797.25 | 1,133.50 | 461.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| Net benefit (GH¢) | 5,288.83 | 4,864.40 | 4,640.54 | 3,611.30 | 3,674.16 | 3,555.97 | 3,180.90 | 4,983.79 | 4,579.24 | 4,253.00 | 3,359.61 | 3,341.57 | 3,326.26 | 2,885.00 |

Source: Field data, Marfo-Ahenkora (2018)

Seed rate was calculated at 20 kg ha$^{-1}$ and GH¢ 1.50 per kg for the local variety; Cost of fertilizer includes fertilizer (cost of 50 kg NPK- GH120.00, cost of Urea 50 kg -GH 115.00) and transportation cost per hectare. Cost of manure was made up of transportation and manure collection fees per hectare (manure was freely available in the community).; Fert + man = 50% Fertiliser + 50% Goat Manure; Control = Farmer practice; RNSF = Residual nutrient sole fertilizer; RNGM = Residual nutrients goat manure; RNF+GM = Residual nutrients fertilizer + goat manure

All the treatment combinations recorded higher net benefits from re-application of soil amendments in the minor season than their residual nutrients plots (residual fertilizer, residual manure and residual fertilizer +manure) in the SDFZ and CSZ (Table 6.8). The percentage increase in net benefits of plants with added nutrients on plots (for all varieties) over that of the residual nutrients ranged from 7.5% to 46.6% in the SDFZ and 3.0% to 51.2% in the CSZ.

In the minor cropping season also, all the varieties had their highest net benefits in the fertilizer + manure treated plots in all the AEZs and the net benefits generally followed a trend in the order: fertilizer + manure > sole fertilizer > sole manure > residual manure > residual fertilizer + manure > residual fertilizer > control. Generally, net benefits of maize for all varieties were higher in the SDFZ compared to the CSZ.

**Table 6.8: Summary of net benefits (GH ¢ ha$^{-1}$) for the three maize varieties under different soil amendments in the minor season**

| AEZ | Maize variety | Net benefits of maize per hectare (GH ¢) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fert+man | Fertilizer | Manure | RNGM | RNF+Gm | RNSF | Control |
| SDFZ | Ahomatea | 3,629.09 | 3,259.12 | 3,139.99 | 2,921.90 | 2,788.02 | 2,776.29 | 2,593.51 |
| | Obatanpa | 5,233.87 | 4,831.80 | 4,599.78 | 3,672.55 | 3,574.74 | 3,520.03 | 3,162.13 |
| | Omankwa | 5,288.83 | 4,864.40 | 4,640.54 | 3,611.30 | 3,607.22 | 3,555.97 | 3,180.90 |
| CSZ | Ahomatea | 3,318.24 | 2,880.23 | 2,749.61 | 2,668.85 | 2,668.10 | 2,572.52 | 2,393.93 |
| | Obatanpa | 4,980.94 | 4,579.24 | 4,243.12 | 3,391.72 | 3,293.41 | 3,152.62 | 2,789.04 |
| | Omankwa | 4,983.79 | 4,528.60 | 4,253.00 | 3,359.61 | 3,341.57 | 3,326.26 | 2,885.00 |

Source: Field data, Marfo-Ahenkora (2018)

RNSF = Residual nutrient sole fertilizer; RNGM = Residual nutrients goat manure; RNF+GM = Residual nutrients fertilizer + goat manure

The percentage net benefit change for planting on sole manure treated plots over the control plot (farmer practice) ranged from 20.3% to 31.9% in the

SDFZ and 6.8% to 29.9% in the CSZ in the major season. In the minor cropping season, the percentage net benefit change for plants on sole manure amended plots over plants on the control plots ranged from 21.1% to 45.9% in the SDFZ and 14.9% to 52.1% in the CSZ. The percentage net benefit change for plants on the sole manure treatments over the control plots was generally higher in the minor cropping season than in the major cropping season (Table 6.9).

**Table 6.9 : Percentage net benefit change for manure treatment over control plots for the three maize varieties in the major and minor seasons in the SDFZ and CSZ**

| Varieties | Percentage net benefit change for manure over the control (Major season) | | Percentage net benefit change for manure over the control (Minor season) | |
|---|---|---|---|---|
| | SDFZ | CSZ | SDFZ | CSZ |
| Ahomatea (local) | 20.3 | 6.8 | 21.1 | 14.9 |
| Obatanpa | 24.1 | 27.7 | 45.5 | 52.1 |
| Omankwa | 31.9 | 29.9 | 45.9 | 47.4 |

Source: Field data, Marfo-Ahenkora (2018)

## 6.5 Discussion

The partial budget analysis has further confirmed the significant role of inorganic fertilizers and / or manure in increasing grain yield and net benefit in maize production in the SDFZ and CSZ. The indication from the partial budget analysis that plants on soil with added nutrients had higher net benefits than plants on the control plots (no amendments) suggest that the added nutrients had positive effects on maize yield and net profits.

In the major cropping season, even though yields were highest in the sole fertilizer treated plots for all the varieties in both SDFZ and CSZ, the economic analysis revealed that the fertilizer + manure treatments gave the highest net benefit for all varieties. The net benefit in the major cropping season which followed the order: fertilizer +manure > sole fertilizer > sole manure >control is probably because of the higher cost of inorganic fertilizer in the price build-up of using 100 % inorganic fertilizer in the sole fertilizer treatment. Comparing the sole fertilizer and the fertilizer +manure treatments, the sole fertilizer gave relatively high total variable cost. A similar observation was made by Nagappa and Biradar (2007) who reported that although vermicompost produce higher yields, the net returns and benefit: cost ratio is low due to the high cost of the vermicompost. Kumar et al. (2005) however reported that in maize, the highest net returns per hectare was obtained with 100% NPK treatment and this contradicts the findings of this current study where the 100% NPK treatments did not give the highest net profit. There is a possibility that, the total variable cost of using 100% NPK by Kumar et al. (2005) was relatively lower than the total variable cost for the 100% NPK used in this study. The results of this current study were also in contrast with findings by Abatania (1998) who reported that, even though the use of chemical fertilizers gives higher gross benefits than the use of manure, the net benefits are higher with the use of manure. In this study, the net benefit was higher for use of sole inorganic fertilizers compared to sole manure. This is probably due to the total variable cost of manure from studies by Abatania (1998) being low or possibly due to much higher yields from the inorganic fertilizer plot in the current study compared to yields obtained from the manure plots.

The higher net benefits from plants on the fertilizer + manure treatments than plants on sole fertilizer and manure treatments in the minor cropping season was an indication that integrated application of manure and inorganic fertilizer was more beneficial over the use of inorganic fertilizer or manure alone for all varieties. The higher profitability of this treatment (fertilizer +manure) was undoubtedly due to the lower total variable cost of this treatment compared to that of the sole fertilizer treatments and could also be due to the higher grain yields originally recorded by plants on the fertilizer + manure treated plots in the minor season.

The observation that 50% inorganic fertilizer + 50% goat manure consistently gave the highest net benefits in this study was also reported by Kalhapure et al. (2013) who observed that the combined application of organic and inorganic fertilizers increased yields to 7.4 t ha$^{-1}$ with highest gross return and net return. Similarly, Saha and Mondal (2006) also reported that judicious application of organic manure along with inorganic fertilizer gave highest net returns and benefit-cost ratio. The integrated use of organic and inorganic nutrient sources has been proven to be economically viable in addition to its potential to improve soil productivity and soil health.

The observation that all the plots with added nutrients yielded higher net benefits than the control (no amendments) was corroborated by Makinde et al. (2007) who reported that farmers could gain better if they changed from no fertilizer (control) to either organic fertilizer or inorganic fertilizer. The implication of this present study is that, farmers will be better off adopting some of these soil amendments rather than not applying any soil amendment as is currently being practiced by most smallholders in the study areas. All the soil amended treatments used in this study can therefore be recommended to farmers since they all increased the net benefit but, for sustainable maize production, amendments with organic manure both alone or in combination with inorganic fertilizer must be upheld and promoted. Badolo (2017) working on sorghum reported that, the cropping system combining manure and chemical fertilizer is most beneficial economically for smallholder farmers in southern Mali. The sole manure treatments which recorded net benefits ranging from 6.8% to 52.1% over the control in both AEZs and cropping seasons had relatively lower total variable cost and could easily be adopted by resource poor farmers since the manure was available in the communities. Chhetri (2016) reported that even if one system gives higher gross/net income, the farmer may choose another system with less profit which also involves less capital investment because of his limited capital resources.

The higher net benefits of Omankwa and Obatanpa over Ahomatea (the local variety) across all soil amended treatments in both AEZs may be due to their inherently higher yielding abilities over the local variety although Omankwa had slightly higher net benefits compared with Obatanpa. The continued use of local varieties by farmers with no nutrient addition to the soil will reduce their yield as well as their net benefits as observed in this study.

For all the varieties, plants on the control plots (no amendments) gave the lowest net benefits across the two AEZs possibly because of the lower yields recorded by plants on the control plots. This presupposes that it is not the best practice to grow maize on continuously cropped lands without adding nutrients to the soil. The lower net benefits obtained by plants on residual nutrients and the control plots implied that it was important to give a second application of soil amendments in the minor cropping season (even if soil amendment were applied in the major season) on continuously cropped lands in order to maintain or make higher profits.

Generally, the three maize varieties in SDFZ recorded higher net benefits than those in the CSZ in both cropping seasons and this is probably because plants in the SDFZ had higher grain yields compared to those in the CSZ.

### 6.6 Chapter summary

- The application of 50% inorganic fertilizer (NPK 125 kg ha$^{-1}$ + Urea 62.5 kg ha$^{-1}$) + 50% goat manure (2.5 t ha$^{-1}$) consistently gave the highest net benefits making it the best soil amendment for all the varieties over the two cropping seasons in both AEZs.
- The higher profitability of this treatment (fertilizer + manure) was due to lower total variable cost compared to the sole fertilizer treatment.
- The sole manure treatments had net benefits ranging from 6.8% to 52.1% over the control in both AEZs and cropping seasons and had relatively lower total variable cost and could easily be adopted by resource poor farmers.
- For all the varieties, plants on the control plots (no amendment) had the lowest net benefits in both AEZs for the two cropping seasons.
- Omankwa and Obatanpa varieties gave higher net benefits than Ahomatea (local variety) but Omankwa gave higher net benefit than Obatanpa.
- Generally, the plots with residual nutrients had lower net benefits compared to their counterparts that had added soil nutrients in the minor cropping season.
- The net benefits from plants on all the residual nutrients plots were however higher than that of plants on the control plots (no amendments) for all the varieties.

- The study showed that it is imperative to apply soil amendments on lands that have been continuously cropped in the major cropping season as well as in the minor cropping season for higher net benefit.
- The maize varieties gave higher net benefits in the SDFZ than in the CSZ because grain yields were relatively higher in the SDFZ than in the CSZ.

# CHAPTER SEVEN

# GENERAL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

## 7.1. General discussions

Smallholder farmers who constitute about 80% of maize producers in Ghana have enormous challenges which are making them produce far below their capacities leading to low average yields nationally (MoFA, 2012). This study sought to explore and diagnose what factors (biophysical, technical, socio cultural and socio economic) were influencing adoptions of relevant technologies in maize production in the study areas with the purpose of situating the subsequent research in the needs of the local farming communities. Understanding the relative importance of these factors was considered a necessary step in contributing to the strategy for the technical interventions to reduce yield gaps for maize in the semi-deciduous forest zone (SDFZ) and coastal savannah zone (CSZ).

The case has been made that one of the reasons why technology adoption is low is that, generally researchers conduct on-station experiments and hand down results to farmers to implement (ie the top-down approach). To meet this difficult challenge of making agricultural research more responsive to the needs of farmers, there was the need to also employ participatory research methodology which is designed to improve the interaction among farmers and researchers. To achieve the objectives of this study therefore, a Participatory Rural Appraisal (PRA) was conducted in the SDFZ and CSZ to explore together with the farmers, their major maize production constraints. This was immediately followed by on-farm experimentations in the two AEZs. The results obtained from the PRA informed the selection of three maize varieties (Ahomatea (local variety), Obatanpa and Omankwa] and different soil amendments (goat manure, inorganic fertilizer and their combination) for a researcher led on- farm experimentations in the major and minor cropping seasons of 2017.

The main findings of this study have been discussed in the individual chapters of this thesis. Therefore the objective of this chapter is to integrate these findings by discussing them, drawing conclusions and suggesting recommendations.

The outcome of the PRA revealed that adoption of sustainable production practices for maize was influenced by socio-cultural, socioeconomic, technical as well as biophysical factors in the study areas of the two AEZs. Unpredictable weather conditions, unstable market prices and risk of crop failure were observed to be some of the major reasons why most farmers did not want to invest in improved technologies such as use of inorganic fertilizer and purchasing of improved seeds. The farmers argued that, if they invest in these inputs and the rainfall was delayed or was too early, it would affect their yields and overall outputs considerably.

Lack of access to formal credit which was a major problem in all the study areas was also one of the reasons why new technologies were not adopted. Credit facilities could help farmers to purchase inputs, expand production areas and acquire more labour for their farming activities.

Majority of farmers practiced slash-and-burn as their land preparation method. This age old practice has the potential to reduce soil productivity greatly coupled with the fact that most of them were not practicing any soil fertility improvement strategies despite the fact that they were engaged in continues cropping. Even though most of the farmers kept some form of livestock it came out that use of manure from the livestock was not part of their soil amendment strategies. Manure from livestock is a relatively cheap source of soil nutrients and was available in all the farming communities studied even though the quantities may not be enough, it is worth adding the available manure to the soil than leaving it to go waste as was the case in the communities studied.

Unfavourable land tenure arrangements that were found to contribute to inadequate soil fertility management resulted in low yields for farmers in the long term. Low plant population which was observed even for those who had adopted row planting, was a recipe for low yields but the farmers argued that low plant population was one of the strategies adapted to overcome declining soil fertility. Some farmers who did not plant improved varieties alluded that the improved varieties did not store well and did not taste good and that applying fertilizer on cultivated maize impacted the taste negatively. These assertions ought to be verified by research. Use of local varieties and farmer saved seed which were widespread in the study areas could possibly be due to lack of knowledge and unavailability of seeds of newly released maize varieties at the local agro-input shops. It is also possible that the farmers cultivated local maize varieties because they could recycle seeds for many seasons.

The next study focused on introducing some improved maize varieties in addition to the local variety under different soil amendments. Two field experiments were conducted in a participatory manner in the two AEZs in the major and minor cropping seasons. The soils at the study sites were deficient in most of the macro nutrients for plant growth (N, P, K, Ca and Mg) with soils in the SDFZ having slightly better nutrient levels than the CSZ. The application of external sources of soil amendments either as mineral fertilizer or manure or both was therefore essential for increased and sustainable maize production in the study areas. The goat manure used at 5 t ha$^{-1}$ provided some micronutrients in addition to macro nutrients (93.5 kg N ha$^{-1}$, 75.5 kg P ha$^{-1}$ and 31 kg K ha$^{-1}$) which were comparable to those contained in the sole inorganic fertilizer (95 kg N ha$^{-1}$, 37.5 kg P ha$^{-1}$ and 37.5 kg K ha$^{-1}$) treatments at the rate that was used in this experiment implying that goat manure could be a valuable nutrient source for sustainable maize production. Rainfall for the period of the experimentation which was generally higher in the SDFZ compared to the CSZ for both cropping seasons probably contributed to higher yields in the SDFZ than the CSZ.

The study revealed that, the influence of the different soil fertility amendments on growth and yield (grains and stover) of maize was generally significant in both AEZs and for both cropping seasons. The effect of application of the different soil amendments (sole fertilizer, sole manure and fertilizer + manure) in improving soil fertility levels and sustainable maize production was demonstrated in the increased grain yields recorded by these amendments compared to the control plot in this study.

In the major cropping season, the observed highest growth and yield recorded on sole inorganic fertilizer treated plots followed by plants on the 50% goat manure + 50% inorganic fertilizer treated plots and sole manure with the least on the control (no amendment) plots was probably due to the fact that under the 100% inorganic fertilizer treatment plots, a lot more nutrients were readily available for easy uptake by the plants. This observation also implied that the sole inorganic fertilizer applied exerted strong positive influence on maize growth, development and yield. The additional nutrients could have caused faster growth and development resulting in higher yields of plants under the sole inorganic fertilizer treatment. Grain yields for all the varieties on the sole fertilizer treatment were higher compared to yields obtained by plants on the combined nutrients (fertilizer + manure) in the major season even though the reverse was the case when the soil amendments were applied again in the minor season.

In the minor season, the use of soil amendments (manure and/or inorganic fertilizer) increased maize growth, grain yields and biomass production. However, the grain yields obtained by the combined treatments were significantly higher than their sole or individual treatments. It can be deduced from this present study that, if goat manure was combined with inorganic fertilizer on continuously cropped land, the effect of the combination may not be felt in the first season of planting but if application was repeated in subsequent seasons, then the synergistic effect of manure and inorganic fertilizer would be seen.

Effect of manure was more pronounced in the minor season, probably because of mineralisation of the manure applied in the major season which made more nutrients available for the plants in the minor season and hence increased grain yields. This was also evident in plants on the residual nutrients where plants on the residual manure had the highest yields among the residual nutrients in the minor season.

Generally, the gaps between the grain yields of maize produced on the control plots and on the plots amended with goat manure across locations and cropping seasons in this study were expected to draw the attention of the farmers and help them to have a better understanding about the value of goat manure in particular and Farm Yard Manure (FYM) as a whole in sustaining maize production. This implied that these organic resources could be used as nutrient sources and could meet the nutrient requirements for maize in smallholder farming systems and give about 80 - 100% higher yields than the current yield of 1.92 t $ha^{-1}$ obtained by farmers who crop without any external inputs in Ghana (MoFA, 2012). The lowest grain and stover yields obtained on the control plots in both cropping seasons was an indication that maize grown on lands that have been subjected to continuous cropping without any soil amendments could result in yield reductions over time as observed for yields on the control plots which reduced from the major cropping season to the minor cropping season in both AEZs. Yields of maize on plots with soil amendments increased from the major to the minor cropping season even though rainfall was much lower in the minor cropping season. The relatively increased yields in the minor cropping season were probably because the plants might have benefitted from residual moisture and residual nutrients from the previous major season. Even though plants on the control plots (no amendments) consistently had the lowest grain yields for all the varieties, all the varieties on control plots had grain yields that were above the national average yield of 1.92 t $ha^{-1}$ indicating the importance of good farm management practices alone on yields.

Obatanpa and Omankwa varieties which demonstrated higher yielding abilities over the local variety (Ahomatea) under all the different soil amendments and for both cropping seasons and AEZs, confirmed the fact that improved varieties produced higher grain yields. Oladejo and Adetunji (2012) also reported that, when local farmers make use of improved seeds, they obtain better yield compared with those who relied on unimproved seeds.

The economic assessment of the soil amendments have also showed that application of 50% goat manure in combination with 50% inorganic fertilizer was more profitable (high net benefit) than the application of the other soil amendments in both cropping seasons. The higher profitability of this treatment was due to the lower total variable costs compared to the 100% inorganic fertilizer and the highest grain yield obtained in the minor cropping season. Even though higher values were obtained for grain yields from the sole inorganic fertilizer treatment in the major season, the economic analysis revealed that plants on the inorganic fertilizer + manure treatments had the highest net benefits.

The observed higher net benefits from re-application of soil amendments in the minor season than their residual nutrients plots (Residual fertilizer, residual manure and residual fertilizer +manure) in both AEZs implied that, on lands that have been continuously cropped, it is important to apply soil amendments in both the major and minor cropping seasons. For sustainable maize yields, it is paramount to include organic sources such as manure to improve organic matter content of the soil and thereby improve fertilizer use efficiency.

## 7.2 Conclusions

- The factors identified as affecting adoption of improved maize production practices included;

-sociocultural (unfavourable land tenure arrangements, slash and burn method of land preparation, alleged poor taste of improved varieties),

-socioeconomic (age, gender, education, lack of access to credit, unstable maize prices, poor marketing systems, Inadequate tractor service for ploughing),

-technical (unavailability of improved varieties, use of farmer saved seeds, predominant use of local varieties, low use of fertilizers and other soil amendments, low plant population, substandard herbicide products on the market) and

-biophysical (unpredictable weather conditions, risk of crop failure) factors.

- Growth and yield of maize was highest on the 100% NPK (sole fertilizer) treated plots in the major cropping season for all varieties.
- The study showed that maize yields in the SDFZ and CSZ of Ghana could be increased using improved maize varieties, recommended fertilizer rates by MoFA, goat manure at 5 t ha$^{-1}$ and the combination of 50% goat manure and 50% inorganic fertilizer.
- Re-application of the combined manure and inorganic fertilizer on maize in the minor cropping season resulted in yields (grain and stover) which were higher than that of plants on the other soil amendments. Inferring that the combination has prospects in the long term than in the first season of planting.
- The plots with residual nutrients had growth, grain and stover yields which were lower than what was obtained from plots with reapplied amendments but higher than plants on the control plots.

- Omankwa and Obatanpa had higher grain yields than the local variety (Ahomatea) in both cropping seasons and AEZs
- Generally, Omankwa variety gave higher yields and matured earlier than the other varieties.
- Even though the yield potential of the local variety is comparatively low, almost all the soil amendments introduced, improved its yields above the national average maize yield of 1.92 t ha $^{-1}$.
- An application rate of 5 t ha$^{-1}$ of goat manure was capable of increasing yields by more than 50% over the control for Obatanpa and Omankwa and about 30% for Ahomatea (local variety).
- The complementary application of manure and inorganic fertilizer is shown to reduce the application rates of each soil amendment type without a significant reduction in the yields of maize. The combined use of organic and inorganic fertilizers is therefore required for sustainable maize crop productivity in the SDFZ and CSZ agro-ecologies.
- Economic benefit analysis in this study showed that the best option for the highest net benefit in maize cultivation was the use of Omankwa/Obatanpa varieties under the inorganic fertilizer + manure treatment and that farmers will be better off with this application in both locations.
- The sole manure treatments which had net benefits ranging from 6.8% to 52.1% over the control in both AEZs and cropping seasons, had relatively lower total variable cost and could easily be adopted by resource poor farmers.

- Plant growth, grain yields and stover production were generally higher in the SDFZ than in the CSZ for both cropping seasons.

## 7.3 Recommendations

- Based on the outcome that most farmers did not have access to formal credit, this study recommends that smallholder farmers be supported to form cooperative groups to support themselves and have leverage so that members could possibly have easy access to loans for farming at reasonable interest rates.
- Policymakers should work to improve land tenure arrangements to create favourable land schemes that will benefit smallholder farmers in these areas.
- It is recommended that subsidized fertilizers be distributed to the major farming communities instead of the district capitals as is being done currently to increase fertilizer accessibility and use.
- Policy makers should support the promotion of a well-organized marketing system that offer stable and realistic maize prices to farmers and put in place mechanisms to overcome some of the market failures that discourage technology adoption.
- Farmer- extension contact has to be strengthened to facilitate adoption of improved technologies to improve maize yields.
- The perception of relatively poor taste of ‘agric’ maize and poor storage quality has to be investigated and addressed by researchers.
- Omankwa has great potential in the study area and its cultivation must be encouraged in this era of climate change since it has a shorter life cycle and can tolerate drought.

- Goat manure is a valuable organic fertilizer and given that farmers have liquidity constraints the use of sole manure is a good option provided adequate quantities of the manure are available.
- The combined application of goat manure (2.5 tons ha$^{-1}$) and inorganic fertilizers (47.5 kg N ha$^{-1}$, 18.8 kg P ha$^{-1}$, 18.8 kg K ha$^{-1}$) is recommended for smallholder farmers in the study areas for attainment of sustainable maize yields and higher net benefits.
- It is recommended that soil amendments be applied in both the major and minor cropping seasons on lands that have been continuously cropped for sustainable maize production.
- It is recommended that this study be conducted in other maize producing agro-ecologies in Ghana.
- Research into the long-term effects of the soil amendments used in this study on nutrient uptake by plants, soil physical and soil chemical properties is recommended.

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# APPENDICES

## APPENDIX A

### QUESTIONNAIRE FOR FARMERS IN TWO AGRO-ECOLOGICAL ZONES.

**PROJECT TITLE: STRATEGIES FOR SUSTAINABLE PRODUCTIVITY OF MAIZE (*ZEA MAYS L.*) - BASED FARMING SYSTEMS OF SMALLHOLDER FARMERS IN GHANA**

Interviewer:..............................................................................

Name of farmer: ……………………………………..............     Phone nº.….…….

Agro-ecological Zone:............................................................

### FARMER BIODATA

1. District ……………………………………………
2. Community/ Location (GPS)……………………………………………………………………………
3. Are you a native of this community?   1. Yes ( )   2. No ( )
4. Mother tongue …………………………
5. Sex: M/F
6. Age group:   1. 21 -30 yrs. ( )   2. 31 – 40 yrs. ( )   3. 41-50 yrs. 4.51-60 yrs. ( )   5. Above 60 ( ).
7. Marital status:   1. Single ( )   2. Married ( )   3. Divorced ( )   4. Widowed ( )
   5. Separated ( ).
8. Level of education: 1. Basic ( )   2. Sec. /Tech. /Voc. ( )   3. Non-Formal Education ( )
9. Religion: 1. Christian ( )   2. Moslem ( )   3. Traditional ( )   4. Others specify..................
10. How long have you been engaged in farming?   1. 1-5 yrs. ( )   2. 6 -10yrs ( )
    3. 11 – 15yrs ( )   4. Above 15yrs ( ).
11. Is farming your main occupation?   1. Yes ( )   2. No ( )
12. What else do you do for a living aside farming?   1. Trading ( )   2. Fishing ( )   3. Formal sector ( )   4. Craftsmanship ( )   5. Others specify..................................................................
13. Does your spouse own separate farm?   1. Yes ( )   2. No ( )
14. Do your children have their own farms?   1. Yes ( )   2. No ( )
15. Is there a household farm?   1. Yes ( )   2. No ( )
16. Do you belong to any farmer Association?   1. Yes ( )   2. No ( )
17. If yes, what type of association?   1. Production ( )   2. Agro-processing ( )
    3. Marketing ( )
    4. Credits (loan) ( ) 5. Others specify.........................................
18. What services do you obtain from the association?   1. Do not benefit ( )
    2. Provision of credit ( )   3. Supply of inputs ( )   4. Marketing of produce ( )
    5. Information on production ( )   6. Other, specify…………………………

**CROP PRODUCTION**

19. Estimate your total land holding (acres)…. …………………………
20. Under what tenure system is your land holding? 1. Family ( ) 2. Sharecropping ( ) 3. Lease ( ) 4. Own land ( ) 6. Other, specify,……………..
21. If tenant/ share cropping what are the terms?....................................................................................
22. Do you have any problem with land acquisition? 1. Yes ( ) 2. No ( )
23. If yes, explain……………………………........................................................................ ........................................................................................................................
24. Do you have access to water for crop farming, other than rain water? 1. Yes ( ) 2. No ( )
25. If yes what is the source? 1. River ( ) 2. Dam ( ) 3. Dug out well ( ) 4. Pipe borne( )
    5. Borehole ( ) 6. Other, specify ……………………………………………
26. Crop holding (in order of importance)

| Type of crop | Acreage | Proportion sold | Proportion for home consumption |
|---|---|---|---|
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |
| 5. | | | |

27. How long have you been engaged in maize farming? 1. 1-5 yrs. ( ) 2. 6 - 10yrs ( )
    3. 11-15yrs ( ) 4. Above 15yrs ( )
28. How do you prepare the land for your maize farm? 1. Slash and burn ( ) 2. Plough with tractor ( ) 3. Zero tillage ( ) 4. Hoe/cutlass –no burning ( ) 5. Slash, burn, herbicide ( ) 6. Other, specify..............................
29. Do you plant in rows? 1. Yes ( ) 2.No ( ).
    If no, what are the reasons? 1. Do not know about it ( ) 2. Do not know how to do it ( ) 3. Waste of time ( ) 4. Do not know its importance ( ) 5. Other, specify..........................................................
30. Which maize varieties have you been cultivating? 1. Obatanpa ( ) 2. Local white ( )
    3. Local yellow ( )4. Golden crystal ( ) 5.Others, specify....................................
31. Why the chosen type(s) 1. High yield ( ) 2. Drought resistance ( ) 3. Good taste ( )
    4. Pest and Disease resistance ( ) 5. Grain quality ( ) 6. Early maturity ( )
    7. Other, Specify………………………………………………………………..
32. Where do you obtain your seed maize? 1. Own farm ( ) 2. Family and friends ( ) 3. Certified seed growers ( ) 4. Agro input shops ( )
    6. Other, specify……….........
33. How many times do you weed your maize farm after planting? 1. Once ( ) 2. Twice ( )
    3. Thrice ( ) 4. Others specify.............................................
34. What weed control method(s) do you use? 1. Herbicide ( ) 2. Hoe ( ) 3. Cutlass ( )
    4. Other, specify ………………………………………

35. Do you practice crop rotation on your maize farm? 1. Yes ( ) 2. No ( )
36. If yes, what is the cropping sequence?..........................................................................................
37. Do you practice Intercropping on your maize farm? 1. Yes ( ) 2. No ( )
38. If yes, what crops do you grow in addition to maize?.........................................................................
39. Why do you intercrop your maize with other crops? 1. Limited farm land ( ) 2. Soil improvement ( ) 3. Avoid complete crop failure ( ) 4. Increased overall productivity ( ) 5. Weed control ( ). 6. Other, specify ……………
40. In your opinion, do the intercrops influence yields of maize? 1. Positively ( ) 2. Negatively ( ) 3. Not sure ( )
41. What is the your estimated grain yield per hectare in your maize farm?................
42. What do you do to your maize after harvesting? 1. Sell fresh cobs ( ) 2. Dry and shell for immediate sale ( ) 3. Process for storage ( ) 4. Other, specify ………….........................
43. How long do you store your grains before selling?............................................
44. How do you treat your crop residue after harvest? 1. Burn ( ) 2. Left on farm as mulch ( ) 3. Gathered and stored as animal feed ( ) 4. Other, specify.........................................................

***Soil fertility management***

45. Have you used fertilizer on your farm in the last 5 years? 1. Yes ( ) 2. No ( )
46. If yes, which type(s)? 1. Inorganic fertilizer ( ) 2. Organic-manure ( ) 3. Organic foliar ( ) 4.Other, specify……………………………………
47. Why this type of fertilizer(s)? 1. Cheaper ( ) 2. More efficient ( ) 3. Easy to apply ( ) 4. Other, specify.........................................................................
48. Where do you obtain your inorganic fertilizer? 1. FBOs ( ) 2. Agro input dealers ( ) 3. NGOs ( ) 5. Other (specify)……………………………………………
49. If you don't apply fertilizer, what are the reasons? 1. Fields fertile ( ) 2. High cost of fertilizer ( ) 3. Bad food taste ( ) 4. Cannot apply ( ) 5. Other (specify)………………………………
50. What other crops receive inorganic fertilizers and why?..........................................................................................................
51. Which types of inorganic fertilizers do you apply? 1. NPK ( ) 2. Urea ( ) 3. Ammonia ( ) 4. Others, specify.......................................................................
52. What method of fertilizer application do you use? 1. Broadcasting ( ) 2. Spraying ( ) 3. Drilling ( ) 4. Ring ( ) 5. Side placement ( ) 6.Others specify…………………………
53. How many bags/litres of fertilizer do you use per hectare on your maize farm.......................................
54. How many times do you apply fertilizer before you harvest your maize? 1. Once ( ) 2. Twice ( ) 3. Other, specify...................................
55. When (what stage) do you apply your fertilizer after planting? 1. 3 weeks ( ) 2. 6 weeks ( ) 3. Other, specify.........................................................................................
56. Do you use manure? 1. Yes ( ) 2. No ( )
57. If yes, which type(s)? 1. Cow dung ( ) 2.Poultry manure ( ) 3.Sheep & goat manure ( ) 4. Pig manure ( ) 5. Other, specify (......................................................................)

58. Do you compost the manure? 1. Yes ( ) 2. No ( )
59. How do you compost your manure before application? 1. Mix with residue and covered ( ) 2. No treatment ( ) 3. Cover with leaves ( ) 4. Other, specify ................................................
60. How do you apply the manure? 1. By spreading on the field and ploughing ( ) 2 Place on soil near individual plants ( ) 3. Put it in holes before planting ( ) 4. Broadcast before planting ( ) 5. Other, specify.........................................................................................................................
61. Can you estimate quantity (No. of bags) of manure used per acre?....................................................
62. Does your soil become soggy when it rains? 1. Yes ( ) 2. No ( ).
63. How would you describe the soil you farm on? 1. Sandy ( ) 2. Sandy Loam ( ) 3. Loamy ( ) 4. Clayey ( ) 5. Other, specify…………………………………………………………

***Climate variability***

64. Has your planting date/time changed within the last five years? 1. Yes ( ) 2. No ( ).
65. Have you change type of crops due to change in weather? 1. Yes ( ) 2. No ( )
66. What have you observed about the planting season year after year? 1. Shifting forward ( ) 2.Shifting backwards ( ) 3. Remain fixed ( ) 4. Other, specify...............................................
67. In your opinion, how will variation in planting season influence your maize yields?...........................
.........................................................................................................................
68. Indicate the season(s) you plant your maize 1. Major ( ) 2. Minor ( ) 3. Both ( )
69. In your estimation, which season gives you the highest yields 1. Major ( ) 2. Minor ( ).
70. What indicators determine the time of land preparation in the major season?
……………………………………….. ………………………………………………….
71. What indicators determine the time of land preparation in the minor season?
………………………………………. ……………………………………………………
72. How do you determine when it is planting time?.................……………………..
73. During which month of the year did you plant major season maize in the past 10 years?
1. February ( ). 2. March ( ) 3. April ( ) 4. May ( )
74. During which month of the year did you use to plant minor season maize in the past 10 years?
1. July ( ) 1. August ( ) 2. September. ( ) 3. October ( ).
75. When do you currently plant in the major season? 1. March ( ) 2. April ( ) 3.May ( )
4. June ( )
76. When do you currently plant in the minor season? 1. July ( ) 1. August ( ) 2. September ( ) 3. October ( )
77. If there is a change in planting dates, what do you think are the causes?
1. Rainfall ( ) 2. Soil nutrient ( ) 3. Soil moisture availability ( )
4. Land preparation ( ) 5. Availability of planting materials (inputs) ( )
6. Pest and disease ( ) 7. High temperatures ( )

78. Which of the following climatic factors has affected your maize production? 1. Drought ( ) 2. Flooding ( ) 3. Strong winds ( ) 4. Late or early rainfall ( ) 7. Others, specify.................................
79. Have you experienced any new insect pest and diseases within the last three years? 1. Yes ( )
 2. No ( )
80. Have you seen new weeds you have never seen before in your farm? 1. Yes ( )
 2. No ( )
81. If yes, what is the nature of this weed?
 .........................................................................................................
82. What time of year do you harvest your major season maize?
 ………………………………………...
83. What time of year do you harvest your minor season maize?
 ..................................................................
84. Are you able to achieve your projected yields every year? 1. Yes ( ) 2.No ( )
85. If yes, what makes you achieve your expected outcome?…………………………
86. If no, what do you think could cause the low productivity?................……………………………..
87. In your opinion, what can you do to achieve your maximum yield potential?.......................................................................................................................
88. List five major constraints you face in your maize farming activities
 ………….......................................................................................................................

## ANIMAL PRODUCTION

89. Do you keep animals in addition to your crop farming? 1. Yes ( ) 2. No ( )
90. Livestock holding; Type and numbers of each livestock.

## EXTENSION AND CREDIT

91. What external assistance do you receive for your farming activities? Source?

| **Service** | **Crops** | **Livestock** | **Source ( who is providing service)** | |
|---|---|---|---|---|
| | | | **Crop** | **Livestock** |
| Training | | | | |
| Technical (extension) | | | | |
| Agricultural Input | | | | |
| Financial | | | | |
| Others (state) | | | | |

92. Do you have access to extension services? 1. Yes 2. No
93. In what ways has extension work helped your farming activities?...........................
94. How do you see the services of extension personnel to you? 1. Very important ( ) 2. Important ( ) 3. Somewhat important ( ) 4. Not very important ( ) 5. Not at all important ( )
95. How do you access extension officers? 1. They visit me ( ) 2. I go to them ( ) 3. Meet at farmers' fora ( ) 4. Phone calls ( ) 5. Other, specify……………………………
96. If they visit you, how often do they visit you? 1. Once in a fortnight ( ) 2. Once in a month ( ) 3. Once in 3 months ( ) 4. Once a year ( ). 5. Other, specify...................
97. Where do they visit you? 1. Farm ( ) 2. Homes ( ) 3. Both ( )
98. Do you have access to credit for your farming activities? 1. Yes ( ) 2. No ( )
99. If yes, where do you get credit from? 1. Bank/ rural bank ( ) 2. Credit union ( ) 3. Family ( ) 4. Friends ( ) 5. NGO's ( ) 6. Other, specify………..
100. Have you benefited from any formal credit scheme in the last two years? 1. Yes ( ) 2. No ( )
101. If you have access to credit how does it help in your farm?..........................
102. Which of these do you use money made from your farm for? 1. Trading ( ) 2. Keeping animals ( ) 3. Savings ( ) 4. Taking care of children in school ( ) 5. Investments ( ) 6. Others, specify...................................................................
103. If saving, where? 1. Financial institution. ( ) 2. At home ( )

3. Credit union ( ) 4.Others, specify.........................................................
104. What marketing challenges do you currently face? 1. None ( ) 2. Transport to market ( ) 3. Low price ( ) 4. Difficult to find buyers ( ) 5. Traders dictate price ( ) 6. Other, specify……………………………………………………………
105. How do market availability and accessibility affect your farming activities?…………………….

***Record Keeping***

106. Do you keep any records? 1. Yes ( ) 2. No ( )
107. If No, why? 1. Cannot write ( ) 2. Do not see the importance ( ) 3. See it as important but cannot write ( ) 4. Other, specify……………………………………………..
108. What kind of records do you keep of your farm operations? 1. Written records ( ) 2.Kept in memory 3.written records/kept in memory ( ) 4. Others, specify.......................................

109. If records are written, which of the following types of records do you write? 1. Production records ( ) 2. Financial records ( ) 3. Other, specify...............................

110. Please indicate type of financial records kept 1. Income ( ) 2. Expenditure ( ) . 3. Income and expenditure ( ) 4. Other, specify................................................................

111. What benefits do you derive from keeping written records?..........................................................................................................

112. Please state any other general comments you have?
……………………………………………….............................................................

# APPENDIX B

## Analysis of variance for phenology, growth, yield and yield attributes in the major cropping season

**PHENOLOGY ANOVA**

| | Days to 50% Silking | | | | | 50% Anthesis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3 | 732.11 | 244.04 | 17.63 | | 3 | 477.08 | 159.03 | 11.37 | |
| Location (L) | 1 | 43.09 | 43.09 | 3.11 | 0.08 | 1 | 10.89 | 10.89 | 0.78 | 0.38 |
| Variety (V | 2 | 13940.56 | 6970.28 | 503.43 | <.001 | 2 | 10057.82 | 5028.91 | 359.51 | <.001 |
| Soil Amendment (SA) | 3 | 725.01 | 241.67 | 17.45 | <.001 | 3 | 380.73 | 126.91 | 9.07 | <.001 |
| L x V | 2 | 14.11 | 7.05 | 0.51 | 0.6 | 2 | 18.12 | 9.06 | 0.65 | 0.52 |
| L x SA | 3 | 5.05 | 1.68 | 0.12 | 0.95 | 3 | 17.35 | 5.78 | 0.41 | 0.74 |
| V x SA | 6 | 59.68 | 9.95 | 0.72 | 0.64 | 6 | 30.11 | 5.02 | 0.36 | 0.9 |
| L x V x SA | 6 | 11.23 | 1.87 | 0.14 | 0.99 | 6 | 6.1 | 1.02 | 0.07 | 1 |
| Residual | 261 | 3613.7 | 13.85 | | | 261 | 3650.98 | 13.99 | | |
| Total | 287 | 19144.54 | | | | 287 | 14649.18 | | | |

| | | | | | ASI | | | | | Days to 50% Maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3 | 30.48 | 10.16 | 1.9 | | 3 | 131.35 | 43.78 | 0.59 | |
| Location (L) | 1 | 10.66 | 10.66 | 2 | 0.16 | 1 | 33.35 | 33.35 | 0.45 | 0.5 |
| Variety (V | 2 | 317.03 | 158.52 | 29.69 | <.001 | 2 | 43762.69 | 21881.35 | 297.3 | <.001 |
| Soil Amendment (SA) | 3 | 65.91 | 21.97 | 4.11 | 0.01 | 3 | 401.38 | 133.79 | 1.82 | 0.14 |
| L x V | 2 | 1 | 0.5 | 0.09 | 0.91 | 2 | 9.69 | 4.85 | 0.07 | 0.94 |
| L x SA | 3 | 8.08 | 2.69 | 0.5 | 0.68 | 3 | 6.38 | 2.12 | 0.03 | 0.99 |
| V x SA | 6 | 7.47 | 1.24 | 0.23 | 0.97 | 6 | 19.42 | 3.24 | 0.04 | 1 |
| L x V x SA | 6 | 6.03 | 1.01 | 0.19 | 0.98 | 6 | 15.08 | 2.51 | 0.03 | 1 |
| Residual | 261 | 1393.68 | 5.34 | | | 261 | 19209.65 | 73.6 | | |
| Total | 287 | 1840.32 | | | | 287 | 63588.99 | | | |

## GROWTH

Analysis of Variance: Plant Height

| | 5 weeks | | | | | 7 weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 462.90 | 154.30 | 0.67 | | 3.00 | 10169.90 | 3390.00 | 6.80 | |
| Location (L) | 1.00 | 6750.60 | 6750.60 | 29.34 | <.001 | 1.00 | 7851.50 | 7851.50 | 15.74 | <.001 |
| Variety (V) | 2.00 | 3128.10 | 1564.00 | 6.80 | 0.00 | 2.00 | 5774.00 | 2887.00 | 5.79 | 0.00 |
| Soil Amendment (SA) | 3.00 | 71082.50 | 23694.20 | 102.97 | <.001 | 3.00 | 124381.20 | 41460.40 | 83.13 | <.001 |
| L x V | 2.00 | 15.50 | 7.70 | 0.03 | 0.97 | 2.00 | 500.90 | 250.40 | 0.50 | 0.61 |
| Lx SA | 3.00 | 269.10 | 89.70 | 0.39 | 0.76 | 3.00 | 412.50 | 137.50 | 0.28 | 0.84 |
| V x SA | 6.00 | 1936.20 | 322.70 | 1.40 | 0.21 | 6.00 | 3083.70 | 513.90 | 1.03 | 0.41 |
| L x V x SA | 6.00 | 761.80 | 127.00 | 0.55 | 0.77 | 6.00 | 1132.80 | 188.80 | 0.38 | 0.89 |
| Residual | 261.00 | 60057.30 | 230.10 | | | 261.00 | 130174.00 | 498.80 | | |
| Total | 287.00 | 144464.10 | | | | 287.00 | 283480.40 | | | |

| | 9 Weeks | | | | | 11 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 3253.00 | 1084.30 | 1.63 | | 3.00 | 3519.10 | 1173.00 | 2.26 | |
| Location (L) | 1.00 | 8688.70 | 8688.70 | 13.04 | <.001 | 1.00 | 8006.50 | 8006.50 | 15.39 | <.001 |
| Variety (V) | 2.00 | 62814.90 | 31407.40 | 47.12 | <.001 | 2.00 | 68640.80 | 34320.40 | 65.98 | <.001 |
| Soil Amendment (SA) | 3.00 | 93840.80 | 31280.30 | 46.93 | <.001 | 3.00 | 90292.60 | 30097.50 | 57.86 | <.001 |
| L x V | 2.00 | 1432.80 | 716.40 | 1.07 | 0.34 | 2.00 | 1560.70 | 780.40 | 1.50 | 0.23 |
| Lx SA | 3.00 | 687.70 | 229.20 | 0.34 | 0.79 | 3.00 | 462.00 | 154.00 | 0.30 | 0.83 |
| V x SA | 6.00 | 1822.00 | 303.70 | 0.46 | 0.84 | 6.00 | 2234.70 | 372.50 | 0.72 | 0.64 |
| L x V x SA | 6.00 | 1099.20 | 183.20 | 0.27 | 0.95 | 6.00 | 838.50 | 139.80 | 0.27 | 0.95 |
| Residual | 261.00 | 173961.40 | 666.50 | | | 261.00 | 135757.50 | 520.10 | | |
| Total | 287.00 | 347600.70 | | | | 287.00 | 311312.40 | | | |

Analysis of Variance: Stem Girth

| | 5 Weeks | | | | | 7 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 4.63 | 1.54 | 2.32 | | 3.00 | 5.98 | 1.99 | 1.57 | |
| Location (L) | 1.00 | 2.31 | 2.31 | 3.48 | 0.06 | 1.00 | 13.97 | 13.97 | 10.99 | 0.00 |
| Variety (V) | 2.00 | 19.83 | 9.91 | 14.94 | <.001 | 2.00 | 28.46 | 14.23 | 11.20 | <.001 |
| Soil Amendment (SA) | 3.00 | 56.02 | 18.67 | 28.15 | <.001 | 3.00 | 64.58 | 21.53 | 16.94 | <.001 |
| L x V | 2.00 | 0.13 | 0.06 | 0.10 | 0.91 | 2.00 | 0.24 | 0.12 | 0.09 | 0.91 |
| Lx SA | 3.00 | 0.01 | 0.00 | 0.00 | 1.00 | 3.00 | 0.41 | 0.14 | 0.11 | 0.96 |
| V x SA | 6.00 | 0.87 | 0.15 | 0.22 | 0.97 | 6.00 | 0.96 | 0.16 | 0.13 | 0.99 |
| L x V x SA | 6.00 | 0.58 | 0.10 | 0.14 | 0.99 | 6.00 | 0.24 | 0.04 | 0.03 | 1.00 |
| Residual | 261.00 | 173.14 | 0.66 | | | 261.00 | 331.67 | 1.27 | | |
| Total | 287.00 | 257.51 | | | | 287.00 | 446.50 | | | |

| | 9 Weeks | | | | | 11 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 9.77 | 3.26 | 3.10 | | 3.00 | 2.16 | 0.72 | 0.64 | |
| Location (L) | 1.00 | 27.64 | 27.64 | 26.28 | <.001 | 1.00 | 13.18 | 13.18 | 11.79 | <.001 |
| Variety (V) | 2.00 | 71.37 | 35.68 | 33.92 | <.001 | 2.00 | 22.32 | 11.16 | 9.98 | <.001 |
| Soil Amendment (SA) | 3.00 | 58.28 | 19.43 | 18.47 | <.001 | 3.00 | 46.46 | 15.49 | 13.85 | <.001 |
| L x V | 2.00 | 0.91 | 0.45 | 0.43 | 0.65 | 2.00 | 1.96 | 0.98 | 0.88 | 0.42 |
| Lx SA | 3.00 | 1.30 | 0.43 | 0.41 | 0.75 | 3.00 | 0.72 | 0.24 | 0.22 | 0.89 |
| V x SA | 6.00 | 0.70 | 0.12 | 0.11 | 1.00 | 6.00 | 1.87 | 0.31 | 0.28 | 0.95 |
| L x V x SA | 6.00 | 0.38 | 0.06 | 0.06 | 1.00 | 6.00 | 1.40 | 0.23 | 0.21 | 0.97 |
| Residual | 261.00 | 274.54 | 1.05 | | | 261.00 | 291.87 | 1.12 | | |
| Total | 287.00 | 444.88 | | | | 287.00 | 381.94 | | | |

Analysis of Variance: Leaf Area

| | 5 Weeks | | | | | 7 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 31472.00 | 10491.00 | 0.13 | | 3.00 | 110529.00 | 36843.00 | 0.24 | |
| Location (L) | 1.00 | 6637337.00 | 6637337.00 | 83.95 | <.001 | 1.00 | 21407658.00 | 21407658.00 | 137.77 | <.001 |
| Variety (V) | 2.00 | 1033710.00 | 516855.00 | 6.54 | 0.00 | 2.00 | 30771439.00 | 15385719.00 | 99.01 | <.001 |
| Soil Amendment (SA) | 3.00 | 20006888.00 | 6668963.00 | 84.35 | <.001 | 3.00 | 68239456.00 | 22746485.00 | 146.38 | <.001 |
| L x V | 2.00 | 15116.00 | 7558.00 | 0.10 | 0.91 | 2.00 | 1541131.00 | 770566.00 | 4.96 | 0.01 |
| Lx SA | 3.00 | 2641251.00 | 880417.00 | 11.14 | <.001 | 3.00 | 313652.00 | 104551.00 | 0.67 | 0.57 |
| V x SA | 6.00 | 305526.00 | 50921.00 | 0.64 | 0.70 | 6.00 | 1571620.00 | 261937.00 | 1.69 | 0.13 |
| L x V x SA | 6.00 | 295651.00 | 49275.00 | 0.62 | 0.71 | 6.00 | 667231.00 | 111205.00 | 0.72 | 0.64 |
| Residual | 261.00 | 20635719.00 | 79064.00 | | | 261.00 | 40556777.00 | 155390.00 | | |
| Total | 287.00 | 51602669.00 | | | | 287.00 | 165179495.00 | | | |

| | 9 Weeks | | | | | 11 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 102175.00 | 34058.00 | 0.16 | | 3.00 | 99535.00 | 33178.00 | 0.11 | |
| Location (L) | 1.00 | 17818707.00 | 17818707.00 | 86.03 | <.001 | 1.00 | 11228411.00 | 11228411.00 | 36.74 | <.001 |
| Variety (V) | 2.00 | 37205078.00 | 18602539.00 | 89.81 | <.001 | 2.00 | 16329394.00 | 8164697.00 | 26.71 | <.001 |
| Soil Amendment (SA) | 3.00 | 81733904.00 | 27244635.00 | 131.53 | <.001 | 3.00 | 56289622.00 | 18763207.00 | 61.39 | <.001 |
| L x V | 2.00 | 1922108.00 | 961054.00 | 4.64 | 0.01 | 2.00 | 2435659.00 | 1217829.00 | 3.98 | 0.02 |
| Lx SA | 3.00 | 260208.00 | 86736.00 | 0.42 | 0.74 | 3.00 | 50372.00 | 16791.00 | 0.05 | 0.98 |
| V x SA | 6.00 | 1535706.00 | 255951.00 | 1.24 | 0.29 | 6.00 | 2803639.00 | 467273.00 | 1.53 | 0.17 |
| L x V x SA | 6.00 | 607320.00 | 101220.00 | 0.49 | 0.82 | 6.00 | 1306654.00 | 217776.00 | 0.71 | 0.64 |
| Residual | 261.00 | 54060553.00 | 207129.00 | | | 261.00 | 79772028.00 | 305640.00 | | |
| Total | 287.00 | 195245759.00 | | | | 287.00 | 170315314.00 | | | |

## YIELD AND YIELD COMPONENTS ANOVA

| Source of variation | Number of cobs per plant | | | | | Number of kernels per row | | | | | Number of kernels per cob | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 0.02 | 0.01 | 1.06 | | 3.00 | 4.18 | 1.39 | 0.13 | | 3.00 | 41016.00 | 13672.00 | 3.52 | |
| Location (L) | 1.00 | 0.20 | 0.20 | 31.30 | <.001 | 1.00 | 22.12 | 22.12 | 2.07 | 0.15 | 1.00 | 11658.00 | 11658.00 | 3.00 | 0.09 |
| Variety (V) | 2.00 | 0.29 | 0.14 | 22.30 | <.001 | 2.00 | 375.97 | 187.99 | 17.57 | <.001 | 2.00 | 69468.00 | 34734.00 | 8.93 | <.001 |
| Soil Amendment (SA) | 3.00 | 1.01 | 0.34 | 51.76 | <.001 | 3.00 | 597.05 | 199.02 | 18.60 | <.001 | 3.00 | 233885.00 | 77962.00 | 20.05 | <.001 |
| L x V | 2.00 | 0.10 | 0.05 | 7.53 | <.001 | 2.00 | 6.72 | 3.36 | 0.31 | 0.73 | 2.00 | 898.00 | 449.00 | 0.12 | 0.89 |
| Lx SA | 3.00 | 0.06 | 0.02 | 2.96 | 0.03 | 3.00 | 9.93 | 3.31 | 0.31 | 0.82 | 3.00 | 6386.00 | 2129.00 | 0.55 | 0.65 |
| V x SA | 6.00 | 0.10 | 0.02 | 2.67 | 0.02 | 6.00 | 44.00 | 7.33 | 0.69 | 0.66 | 6.00 | 20602.00 | 3434.00 | 0.88 | 0.51 |
| L x V x SA | 6.00 | 0.04 | 0.01 | 1.00 | 0.42 | 6.00 | 13.92 | 2.32 | 0.22 | 0.97 | 6.00 | 1862.00 | 310.00 | 0.08 | 1.00 |
| Residual | 261.00 | 1.70 | 0.01 | | | 261.00 | 2792.09 | 10.70 | | | 261.00 | 1014830.00 | 3888.00 | | |
| Total | 287.00 | 3.52 | | | | 287.00 | 3865.99 | | | | 287.00 | 1400603.00 | | | |

| Source of variation | Number of kernel rows per cob | | | | | Cob Weight | | | | | Cob diameter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 44.63 | 14.88 | 7.14 | | 3.00 | 822.00 | 274.00 | 0.17 | | 3.00 | 0.54 | 0.18 | 1.83 | |
| Location (L) | 1.00 | 13.85 | 13.85 | 6.65 | 0.01 | 1.00 | 8125.00 | 8125.00 | 5.17 | 0.02 | 1.00 | 4.35 | 4.35 | 44.44 | <.001 |
| Variety (V) | 2.00 | 54.61 | 27.30 | 13.11 | <.001 | 2.00 | 115397.00 | 57698.00 | 36.69 | <.001 | 2.00 | 16.83 | 8.41 | 85.89 | <.001 |
| Soil Amendment (SA) | 3.00 | 82.57 | 27.52 | 13.22 | <.001 | 3.00 | 71966.00 | 23989.00 | 15.25 | <.001 | 3.00 | 8.76 | 2.92 | 29.82 | <.001 |
| L x V | 2.00 | 2.45 | 1.22 | 0.59 | 0.56 | 2.00 | 1050.00 | 525.00 | 0.33 | 0.72 | 2.00 | 1.92 | 0.96 | 9.81 | <.001 |
| Lx SA | 3.00 | 1.38 | 0.46 | 0.22 | 0.88 | 3.00 | 580.00 | 193.00 | 0.12 | 0.95 | 3.00 | 0.41 | 0.14 | 1.40 | 0.24 |
| V x SA | 6.00 | 5.22 | 0.87 | 0.42 | 0.87 | 6.00 | 5976.00 | 996.00 | 0.63 | 0.70 | 6.00 | 0.22 | 0.04 | 0.38 | 0.89 |
| L x V x SA | 6.00 | 4.52 | 0.75 | 0.36 | 0.90 | 6.00 | 1542.00 | 257.00 | 0.16 | 0.99 | 6.00 | 0.36 | 0.06 | 0.61 | 0.72 |
| Residual | 261.00 | 543.57 | 2.08 | | | 261.00 | 410472.00 | 1573.00 | | | 261.00 | 25.57 | 0.10 | | |
| Total | 287.00 | 752.80 | | | | 287.00 | 615930.00 | | | | 287.00 | 58.97 | | | |

| Source of variation | Cob length | | | | | Weight of 1000 grains | | | | | Cob diameter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 25.89 | 8.63 | 3.50 | | 3.00 | 46.00 | 15.30 | 0.13 | | 3.00 | 78476 | 26159.00 | 1.29 | |
| Location (L) | 1.00 | 10.55 | 10.55 | 4.28 | 0.04 | 1.00 | 5050.1 | 5050.10 | 42.84 | <.001 | 1.00 | 4426627 | 4426627 | 217.83 | <.001 |
| Variety (V) | 2.00 | 67.96 | 33.98 | 13.79 | <.001 | 2.00 | 66620.3 | 33310.20 | 282.58 | <.001 | 2.00 | 68783900 | 3439195 | 1692.43 | <.001 |
| Soil Amendment (SA) | 3.00 | 281.69 | 93.90 | 38.12 | <.001 | 3.00 | 122134 | 40711.30 | 345.37 | <.001 | 3.00 | 160277609 | 53425870 | 2629.09 | <.001 |
| L x V | 2.00 | 0.96 | 0.48 | 0.19 | 0.82 | 2.00 | 565.60 | 282.80 | 2.40 | 0.09 | 2.00 | 29508.00 | 14754.00 | 0.73 | 0.49 |
| Lx SA | 3.00 | 4.69 | 1.56 | 0.63 | 0.59 | 3.00 | 478.40 | 159.50 | 1.35 | 0.26 | 3.00 | 143310.00 | 47770.00 | 2.35 | 0.07 |
| V x SA | 6.00 | 14.63 | 2.44 | 0.99 | 0.43 | 6.00 | 2709.10 | 451.50 | 3.83 | 0.00 | 6.00 | 7488274.00 | 1248046 | 61.42 | <.001 |
| L x V x SA | 6.00 | 2.65 | 0.44 | 0.18 | 0.98 | 6.00 | 584.60 | 97.40 | 0.83 | 0.55 | 6.00 | 257140.00 | 42857 | 2.11 | 0.05 |
| Residual | 261.00 | 642.93 | 2.46 | | | 261.00 | 30765.8 | 117.90 | | | 261.00 | 5303790.00 | 20321 | | |
| Total | 287.00 | 1051.93 | | | | 287.00 | 228954 | | | | | | | | |

| | Stover Weight per hectare | | | | |
|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 3.00 | 245771.00 | 81924.00 | 0.57 | |
| Location (L) | 1.00 | 17254875.00 | 17254875.00 | 119.21 | <.001 |
| Variety (V | 2.00 | 6785405.00 | 3392702.00 | 23.44 | <.001 |
| Soil Amendment (SA) | 3.00 | 321483693.00 | 107161231.00 | 740.32 | <.001 |
| L x V | 2.00 | 258296.00 | 129148.00 | 0.89 | 0.41 |
| L x SA | 3.00 | 10451908.00 | 3483969.00 | 24.07 | <.001 |
| V x SA | 6.00 | 912602.00 | 152100.00 | 1.05 | 0.39 |
| L x V x SA | 6.00 | 824116.00 | 137353.00 | 0.95 | 0.46 |
| Residual | 261.00 | 37779643.00 | 144750.00 | | |
| Total | 287.00 | 395996307.00 | | | |

# APPENDIX C

## Analysis of variance for phenology, growth, yield and yield attributes in the minor cropping season

### PHENOLOGY ANOVA

| | Days to 50% Silking | | | | | Days to 50% Anthesis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 365.64 | 33.24 | 0.56 | | 11.00 | 429.88 | 39.08 | 0.78 | |
| Location (L) | 1.00 | 347.67 | 347.67 | 5.86 | 0.03 | 1.00 | 268.93 | 268.93 | 5.36 | 0.04 |
| Residual (R) | 11.00 | 652.59 | 59.33 | 3.33 | | 11.00 | 551.77 | 50.16 | 4.01 | |
| Variety (V) | 2.00 | 18029.55 | 9014.78 | 505.38 | <.001 | 2.00 | 12388.40 | 6194.20 | 494.91 | <.001 |
| L x V | 2.00 | 30.65 | 15.32 | 0.86 | 0.43 | 2.00 | 11.81 | 5.90 | 0.47 | 0.63 |
| Residual | 44.00 | 784.85 | 17.84 | 2.26 | | 44.00 | 550.70 | 12.52 | 1.47 | |
| Soil Amendment (SA) | 6.00 | 499.25 | 83.21 | 10.54 | <.001 | 6.00 | 272.41 | 45.40 | 5.32 | <.001 |
| L x SA | 6.00 | 51.38 | 8.56 | 1.08 | 0.37 | 6.00 | 62.22 | 10.37 | 1.22 | 0.30 |
| V x SA | 12.00 | 40.31 | 3.36 | 0.43 | 0.95 | 12.00 | 26.17 | 2.18 | 0.26 | 1.00 |
| L x V x SA | 12.00 | 57.55 | 4.80 | 0.61 | 0.84 | 12.00 | 22.62 | 1.89 | 0.22 | 1.00 |
| Residual | 396.00 | 3127.17 | 7.90 | | | 396.00 | 3377.57 | 8.53 | | |
| Total | 503.00 | 23986.60 | | | | 503.00 | 17962.47 | | | |

| | ASI | | | | | Days to 50% Maturity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 49.64 | 4.51 | 0.93 | | 11.00 | 924.26 | 84.02 | 0.79 | |
| Location (L) | 1.00 | 5.05 | 5.05 | 1.04 | 0.33 | 1.00 | 425.34 | 425.34 | 4.01 | 0.07 |
| Residual (R) | 11 | 53.516 | 4.865 | 1.14 | | 11.00 | 1165.55 | 105.96 | 4.66 | |
| Variety (V) | 2.00 | 528.35 | 264.18 | 62.09 | <.001 | 2.00 | 79350.53 | 39675.26 | 1744.40 | <.001 |
| L x V | 2.00 | 4.61 | 2.31 | 0.54 | 0.59 | 2.00 | 16.81 | 8.41 | 0.37 | 0.69 |
| Residual | 44.00 | 187.20 | 4.26 | 1.11 | | 44.00 | 1000.75 | 22.74 | 0.60 | |
| Soil Amendment (SA) | 6.00 | 46.23 | 7.70 | 2.00 | 0.06 | 6.00 | 1080.53 | 180.09 | 4.77 | <.001 |
| L x SA | 6.00 | 1.50 | 0.25 | 0.07 | 1.00 | 6.00 | 10.23 | 1.71 | 0.05 | 1.00 |
| V x SA | 12.00 | 82.01 | 6.83 | 1.78 | 0.05 | 12.00 | 61.39 | 5.12 | 0.14 | 1.00 |
| L x V x SA | 12.00 | 66.59 | 5.55 | 1.44 | 0.14 | 12.00 | 20.33 | 1.69 | 0.04 | 1.00 |
| R | 396.00 | 1522.14 | 3.84 | | | 396.00 | 14965.52 | 37.79 | | |
| Total | 503.00 | 2546.84 | | | | 503.00 | 99021.24 | | | |

## GROWTH ANOVA

| Source of variation | Plant height at 5 Weeks | | | | | Plant height at 5 Weeks | | | | | Plant height at 5 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 8803.80 | 800.30 | 1.16 | | 11.00 | 4372.20 | 397.50 | 0.65 | | 11.00 | 7907.40 | 718.90 | 0.59 | |
| Location (L) | 1.00 | 10251.50 | 10251.50 | 14.83 | 0.00 | 1.00 | 8208.80 | 8208.80 | 13.43 | 0.00 | 1.00 | 4816.40 | 4816.40 | 3.95 | 0.07 |
| Residual | 11.00 | 7605.60 | 691.40 | 2.64 | | 11.00 | 6724.20 | 611.30 | 1.04 | | 11.00 | 13415.20 | 1219.60 | 2.59 | |
| Variety (V) | 2.00 | 7732.20 | 3866.10 | 14.75 | <.001 | 2.00 | 36653.50 | 18326.70 | 31.23 | <.001 | 2.00 | 25513.70 | 12756.90 | 27.07 | <.001 |
| L x V | 2.00 | 906.70 | 453.30 | 1.73 | 0.19 | 2.00 | 748.20 | 374.10 | 0.64 | 0.53 | 2.00 | 1235.30 | 617.70 | 1.31 | 0.28 |
| Residual | 44.00 | 11536.30 | 262.20 | 1.48 | | 44.00 | 25817.10 | 586.80 | 1.28 | | 44.00 | 20732.50 | 471.20 | 1.02 | |
| Soil Amendment (SA) | 6.00 | 51420.60 | 8570.10 | 48.37 | <.001 | 6.00 | 106124.10 | 17687.40 | 38.51 | <.001 | 6.00 | 65519.00 | 10919.80 | 23.63 | <.001 |
| L x SA | 6.00 | 339.80 | 56.60 | 0.32 | 0.93 | 6.00 | 942.40 | 157.10 | 0.34 | 0.91 | 6.00 | 312.10 | 52.00 | 0.11 | 1.00 |
| V x SA | 12.00 | 606.00 | 50.50 | 0.29 | 0.99 | 12.00 | 1662.30 | 138.50 | 0.30 | 0.99 | 12.00 | 354.60 | 29.60 | 0.06 | 1.00 |
| L x V x SA | 12.00 | 614.10 | 51.20 | 0.29 | 0.99 | 12.00 | 542.00 | 45.20 | 0.10 | 1.00 | 12.00 | 1286.00 | 107.20 | 0.23 | 1.00 |
| Residual | 396.00 | 70167.00 | 177.20 | | | 396.00 | 181865.30 | 459.30 | | | 396.00 | 183031.80 | 462.20 | | |
| Total | 503.00 | 169983.70 | | | | 503.00 | 373660.10 | | | | 503.00 | 324124.10 | | | |

| Source of variation | Plant height at 11 Weeks | | | | | Stem girth at 5 Weeks | | | | | Stem girth at 7 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 8161.10 | 741.90 | 0.98 | | 11.00 | 22.86 | 2.08 | 0.75 | | 11.00 | 30.78 | 2.80 | 0.81 | |
| Location (L) | 1.00 | 4731.70 | 4731.70 | 6.23 | 0.03 | 1.00 | 2.85 | 2.85 | 1.02 | 0.33 | 1.00 | 3.95 | 3.95 | 1.14 | 0.31 |
| Residual | 11.00 | 8357.00 | 759.70 | 1.05 | | 11.00 | 30.63 | 2.78 | 2.66 | | 11.00 | 38.05 | 3.46 | 3.52 | |
| Variety (V) | 2.00 | 31620.20 | 15810.10 | 21.77 | <.001 | 2.00 | 2.53 | 1.26 | 1.21 | 0.31 | 2.00 | 5.69 | 2.85 | 2.90 | 0.07 |
| L x V | 2.00 | 1083.80 | 541.90 | 0.75 | 0.48 | 2.00 | 0.76 | 0.38 | 0.36 | 0.70 | 2.00 | 0.70 | 0.35 | 0.35 | 0.70 |
| Residual | 44.00 | 31949.50 | 726.10 | 1.53 | | 44.00 | 46.06 | 1.05 | 1.33 | | 44.00 | 43.20 | 0.98 | 1.03 | |
| Soil Amendment (SA) | 6.00 | 64373.70 | 10728.90 | 22.64 | <.001 | 6.00 | 28.83 | 4.81 | 6.10 | <.001 | 6.00 | 24.74 | 4.12 | 4.32 | <.001 |
| L x SA | 6.00 | 251.30 | 41.90 | 0.09 | 1.00 | 6.00 | 0.13 | 0.02 | 0.03 | 1.00 | 6.00 | 0.16 | 0.03 | 0.03 | 1.00 |
| V x SA | 12.00 | 543.00 | 45.20 | 0.10 | 1.00 | 12.00 | 0.18 | 0.02 | 0.02 | 1.00 | 12.00 | 1.31 | 0.11 | 0.11 | 1.00 |
| L x V x SA | 12.00 | 1176.90 | 98.10 | 0.21 | 1.00 | 12.00 | 0.17 | 0.01 | 0.02 | 1.00 | 12.00 | 0.19 | 0.02 | 0.02 | 1.00 |
| Residual | 396.00 | 187631.90 | 473.80 | | | 396.00 | 312.04 | 0.79 | | | 396.00 | 378.09 | 0.95 | | |
| Total | 503.00 | 339880.10 | | | | 503.00 | 447.04 | | | | 503.00 | 526.86 | | | |

| Source of variation | Stem girth at 9 Weeks | | | | | Stem girth at 11 Weeks | | | | | Leaf area at 5 Weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 6.52 | 0.59 | 0.36 | | 11.00 | 35.37 | 3.22 | 1.27 | | 11.00 | 9937018.00 | 903365.00 | 26.77 | |
| Location (L) | 1.00 | 1.00 | 1.00 | 0.61 | 0.45 | 1.00 | 1.81 | 1.81 | 0.72 | 0.42 | 1.00 | 2267810.00 | 2267810.00 | 67.19 | <.001 |
| Residual | 11.00 | 18.02 | 1.64 | 1.14 | | 11.00 | 27.76 | 2.52 | 4.20 | | 11.00 | 371253.00 | 33750.00 | 0.21 | |
| Variety (V) | 2.00 | 50.51 | 25.25 | 17.57 | <.001 | 2.00 | 53.94 | 26.97 | 44.90 | <.001 | 2.00 | 136993.00 | 68496.00 | 0.42 | 0.66 |
| L x V | 2.00 | 0.38 | 0.19 | 0.13 | 0.88 | 2.00 | 2.31 | 1.15 | 1.92 | 0.16 | 2.00 | 888973.00 | 444486.00 | 2.75 | 0.08 |
| Residual | 44.00 | 63.23 | 1.44 | 1.40 | | 44.00 | 26.43 | 0.60 | 0.60 | | 44.00 | 7116664.00 | 161742.00 | 2.59 | |
| Soil Amendment (SA) | 6.00 | 23.79 | 3.97 | 3.86 | <.001 | 6.00 | 25.34 | 4.22 | 4.21 | <.001 | 6.00 | 68593490.00 | 11432248.00 | 182.96 | <.001 |
| L x SA | 6.00 | 0.02 | 0.00 | 0.00 | 1.00 | 6.00 | 4.55 | 0.76 | 0.76 | 0.61 | 6.00 | 48584.00 | 8097.00 | 0.13 | 0.99 |
| V x SA | 12.00 | 1.34 | 0.11 | 0.11 | 1.00 | 12.00 | 4.59 | 0.38 | 0.38 | 0.97 | 12.00 | 540359.00 | 45030.00 | 0.72 | 0.73 |
| L x V x SA | 12.00 | 0.27 | 0.02 | 0.02 | 1.00 | 12.00 | 6.97 | 0.58 | 0.58 | 0.86 | 12.00 | 151061.00 | 12588.00 | 0.20 | 1.00 |
| Residual | 396.00 | 407.27 | 1.03 | | | 396.00 | 397.43 | 1.00 | | | 396.00 | 24743629.00 | 62484.00 | | |
| Total | 503.00 | 572.35 | | | | 503.00 | 586.48 | | | | 503.00 | 114795832.00 | | | |

| | Leaf area at 7 weeks | | | | | Leaf area at 9 weeks | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 11562852.00 | 1051168.00 | 3.31 | | 11.00 | 15983820.00 | 1453075.00 | 3.09 | |
| Location (L) | 1.00 | 10226221.00 | 10226221.00 | 32.20 | <.001 | 1.00 | 8430189.00 | 8430189.00 | 17.92 | 0.00 |
| Residual | 11.00 | 3493245.00 | 317568.00 | 0.90 | | 11.00 | 5175731.00 | 470521.00 | 2.35 | |
| Variety (V) | 2.00 | 14915807.00 | 7457903.00 | 21.11 | <.001 | 2.00 | 8150004.00 | 4075002.00 | 20.36 | <.001 |
| L x V | 2.00 | 89553.00 | 44777.00 | 0.13 | 0.88 | 2.00 | 93181.00 | 46591.00 | 0.23 | 0.79 |
| Residual | 44.00 | 15542255.00 | 353233.00 | 2.06 | | 44.00 | 8807264.00 | 200165.00 | 1.32 | |
| Soil Amendment (SA) | 6.00 | 147510877.00 | 24585146.00 | 143.63 | <.001 | 6.00 | 151332186.00 | 25222031.00 | 166.37 | <.001 |
| L x SA | 6.00 | 1733163.00 | 288861.00 | 1.69 | 0.12 | 6.00 | 775586.00 | 129264.00 | 0.85 | 0.53 |
| V x SA | 12.00 | 772860.00 | 64405.00 | 0.38 | 0.97 | 12.00 | 443436.00 | 36953.00 | 0.24 | 1.00 |
| L x V x SA | 12.00 | 386881.00 | 32240.00 | 0.19 | 1.00 | 12.00 | 606476.00 | 50540.00 | 0.33 | 0.98 |
| Residual | 396.00 | 67783838.00 | 171171.00 | | | 396.00 | 60033630.00 | 151600.00 | | |
| Total | 503.00 | 274017553.00 | | | | 503.00 | 259831503.00 | | | |

| | | Leaf area at 11 weeks | | | |
|---|---|---|---|---|---|
| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 11562852.00 | 1051168.00 | 3.31 | |
| Location (L) | 1.00 | 10226221.00 | 10226221.00 | 32.20 | <.001 |
| Residual | 11.00 | 3493245.00 | 317568.00 | 0.90 | |
| Variety (V) | 2.00 | 14915807.00 | 7457903.00 | 21.11 | <.001 |
| L x V | 2.00 | 89553.00 | 44777.00 | 0.13 | 0.88 |
| Residual | 44.00 | 15542255.00 | 353233.00 | 2.06 | |
| Soil Amendment (SA) | 6.00 | 147510877.00 | 24585146.00 | 143.63 | <.001 |
| L x SA | 6.00 | 1733163.00 | 288861.00 | 1.69 | 0.12 |
| V x SA | 12.00 | 772860.00 | 64405.00 | 0.38 | 0.97 |
| L x V x SA | 12.00 | 386881.00 | 32240.00 | 0.19 | 1.00 |
| Residual | 396.00 | 67783838.00 | 171171.00 | | |
| Total | 503.00 | 274017553.00 | | | |

## YIELD AND YIELD COMPONENTS ANOVA

| Source of variation | No. of kernels per cob | | | | | No. of kernels per row | | | | | Cob diameter | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 167746.00 | 15250.00 | 1.23 | | 11.00 | 772.09 | 70.19 | 1.36 | | 11.00 | 5.46 | 0.50 | 1.67 | |
| Location (L) | 1.00 | 59479.00 | 59479.00 | 4.80 | 0.05 | 1.00 | 258.72 | 258.72 | 5.01 | 0.05 | 1.00 | 3.41 | 3.41 | 11.46 | 0.01 |
| Residual | 11.00 | 136177.00 | 12380.00 | 2.74 | | 11.00 | 568.32 | 51.67 | 6.46 | | 11.00 | 3.27 | 0.30 | 2.17 | |
| Variety (V) | 2.00 | 136996.00 | 68498.00 | 15.14 | <.001 | 2.00 | 251.33 | 125.67 | 15.72 | <.001 | 2.00 | 62.53 | 31.26 | 227.94 | <.001 |
| L x V | 2.00 | 5872.00 | 2936.00 | 0.65 | 0.53 | 2.00 | 12.20 | 6.10 | 0.76 | 0.47 | 2.00 | 0.01 | 0.01 | 0.05 | 0.96 |
| Residual | 44.00 | 199096.00 | 4525.00 | 2.60 | | 44.00 | 351.82 | 8.00 | 0.97 | | 44.00 | 6.03 | 0.14 | 1.94 | |
| Soil Amendment (SA) | 6.00 | 1208156.00 | 201359.00 | 115.72 | <.001 | 6.00 | 2899.42 | 483.24 | 58.45 | <.001 | 6.00 | 36.98 | 6.16 | 86.98 | <.001 |
| L x SA | 6.00 | 18946.00 | 3158.00 | 1.81 | 0.10 | 6.00 | 151.62 | 25.27 | 3.06 | 0.01 | 6.00 | 0.57 | 0.10 | 1.35 | 0.23 |
| V x SA | 12.00 | 26363.00 | 2197.00 | 1.26 | 0.24 | 12.00 | 46.23 | 3.85 | 0.47 | 0.93 | 12.00 | 2.17 | 0.18 | 2.55 | 0.00 |
| L x V x SA | 12.00 | 15588.00 | 1299.00 | 0.75 | 0.71 | 12.00 | 37.31 | 3.11 | 0.38 | 0.97 | 12.00 | 1.09 | 0.09 | 1.28 | 0.23 |
| Residual | 396.00 | 689061.00 | 1740.00 | | | 396.00 | 3273.68 | 8.27 | | | 396.00 | 28.06 | 0.07 | | |
| Total | 503.00 | 2663481.00 | | | | 503.00 | 8622.75 | | | | 503.00 | 149.57 | | | |

| Source of variation | Cob length | | | | | No. of cobs per plant | | | | | No. of kernel rows per cob | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 113.49 | 10.32 | 2.18 | | 11.00 | 0.09 | 0.01 | 2.58 | | 11.00 | 28.98 | 2.63 | 0.95 | |
| Location (L) | 1.00 | 171.82 | 171.82 | 36.38 | <.001 | 1.00 | 0.04 | 0.04 | 11.20 | 0.01 | 1.00 | 7.07 | 7.07 | 2.55 | 0.14 |
| Residual | 11.00 | 51.95 | 4.72 | 4.82 | | 11.00 | 0.04 | 0.00 | 0.71 | | 11.00 | 30.52 | 2.77 | 3.77 | |
| Variety (V) | 2.00 | 68.96 | 34.48 | 35.20 | <.001 | 2.00 | 0.03 | 0.02 | 3.64 | 0.03 | 2.00 | 75.19 | 37.60 | 51.02 | <.001 |
| L x V | 2.00 | 9.33 | 4.67 | 4.76 | 0.01 | 2.00 | 0.00 | 0.00 | 0.01 | 0.99 | 2.00 | 1.23 | 0.61 | 0.83 | 0.44 |
| Residual | 44.00 | 43.10 | 0.98 | 0.91 | | 44.00 | 0.20 | 0.00 | 1.32 | | 44.00 | 32.43 | 0.74 | 0.79 | |
| Soil Amendment (SA) | 6.00 | 685.26 | 114.21 | 105.82 | <.001 | 6.00 | 0.80 | 0.13 | 39.33 | <.001 | 6.00 | 171.17 | 28.53 | 30.66 | <.001 |
| L x SA | 6.00 | 9.19 | 1.53 | 1.42 | 0.21 | 6.00 | 0.01 | 0.00 | 0.47 | 0.83 | 6.00 | 4.18 | 0.70 | 0.75 | 0.61 |
| V x SA | 12.00 | 20.91 | 1.74 | 1.61 | 0.09 | 12.00 | 0.04 | 0.00 | 1.06 | 0.39 | 12.00 | 4.33 | 0.36 | 0.39 | 0.97 |
| L x V x SA | 12.00 | 8.03 | 0.67 | 0.62 | 0.83 | 12.00 | 0.01 | 0.00 | 0.31 | 0.99 | 12.00 | 3.49 | 0.29 | 0.31 | 0.99 |
| Residual | 396.00 | 427.40 | 1.08 | | | 396.00 | 1.34 | 0.00 | | | 396.00 | 368.45 | 0.93 | | |
| Total | 503.00 | 1609.44 | | | | 503.00 | 2.60 | | | | 503.00 | 727.04 | | | |

| | Weight of stover | | | | | 1000 Grain weight | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | d.f. (mv) | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 32054578.00 | 2914053.00 | 14.49 | | 11.00 | 12428.40 | 1129.90 | 1.42 | |
| Location (L) | 1.00 | 13940730.00 | 13940730.00 | 69.32 | <.001 | 1.00 | 9909.20 | 9909.20 | 12.43 | 0.01 |
| Residual | 11.00 | 2212261.00 | 201115.00 | 1.45 | | 11.00 | 8770.20 | 797.30 | 2.27 | |
| Variety (V) | 2.00 | 7272956.00 | 3636478.00 | 26.28 | <.001 | 2.00 | 74943.70 | 37471.80 | 106.56 | <.001 |
| L x V | 2.00 | 347212.00 | 173606.00 | 1.25 | 0.30 | 2.00 | 241.90 | 120.90 | 0.34 | 0.71 |
| Residual | 44.00 | 6088479.00 | 138375.00 | 1.92 | | 44.00 | 15473.30 | 351.70 | 2.07 | |
| Soil Amendment (SA) | 6.00 | 831682100.00 | 138613683.00 | 1921.99 | <.001 | 6.00 | 201724.30 | 33620.70 | 197.82 | <.001 |
| L x SA | 6.00 | 4635323.00 | 772554.00 | 10.71 | <.001 | 6.00 | 891.00 | 148.50 | 0.87 | 0.51 |
| V x SA | 12.00 | 3177526.00 | 264794.00 | 3.67 | <.001 | 12.00 | 4376.60 | 364.70 | 2.15 | 0.01 |
| L x V x SA | 12.00 | 1983880.00 | 165323.00 | 2.29 | 0.01 | 12.00 | 2455.10 | 204.60 | 1.20 | 0.28 |
| Residual | 396.00 | 28559543.00 | 72120.00 | | | 396.00 | 67301.70 | 170.00 | | |
| Total | 503.00 | 931954587.00 | | | | 503.00 | 398515.40 | | | |

| Source of variation | Weight per cob | | | | | Grain Yield | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | d.f. | s.s. | m.s. | v.r. | F pr. | d.f. | s.s. | m.s. | v.r. | F pr. |
| Reps stratum | 11.00 | 78247.30 | 7113.40 | 2.00 | | 11.00 | 596098.00 | 54191.00 | 1.04 | |
| Location (L) | 1.00 | 17727.90 | 17727.90 | 4.98 | 0.05 | 1.00 | 6957631.00 | 6957631.00 | 133.45 | <.001 |
| Residual | 11.00 | 39173.00 | 3561.20 | 2.09 | | 11.00 | 573503.00 | 52137.00 | 10.55 | |
| Variety (V) | 2.00 | 226453.70 | 113226.90 | 66.60 | <.001 | 2.00 | 94200681.00 | 47100341.00 | 9527.60 | <.001 |
| L x V | 2.00 | 980.10 | 490.00 | 0.29 | 0.75 | 2.00 | 27217.00 | 13608.00 | 2.75 | 0.08 |
| Residual | 44.00 | 74800.60 | 1700.00 | 6.40 | | 44.00 | 217517.00 | 4944.00 | 0.87 | |
| Soil Amendment (SA) | 6.00 | 896949.10 | 149491.50 | 563.16 | <.001 | 6.00 | 295808405.00 | 49301401.00 | 8685.11 | <.001 |
| L x SA | 6.00 | 1927.90 | 321.30 | 1.21 | 0.30 | 6.00 | 173477.00 | 28913.00 | 5.09 | <.001 |
| V x SA | 12.00 | 16706.00 | 1392.20 | 5.24 | <.001 | 12.00 | 15875337.00 | 1322945.00 | 233.05 | <.001 |
| L x V x SA | 12.00 | 3168.60 | 264.00 | 0.99 | 0.45 | 12.00 | 203761.00 | 16980.00 | 2.99 | <.001 |
| Residual | 396.00 | 105119.50 | 265.50 | | | 395 (1) | 2242236.00 | 5677.00 | | |
| Total | 503.00 | 1461253.60 | | | | 502 (1) | 416841676.00 | | | |

# APPENDIX D

## Inputs and operation cost of items included in the total variable cost

| Inputs and operation | Quantity/ha | Unit cost GH¢ | Total cost GH¢ |
|---|---|---|---|
| **Maize seeds** | | | |
| Ahomatea (Local) | 20 kg | 1.50 | 30.00 |
| Obatanpa | 20 kg | 5.00 | 100.00 |
| Omankwa | 20 kg | 5.00 | 100.00 |
| **Inorganic fertilizer** | | | |
| NPK 15-15-15 | 5 bags | 120.00 | 600.00 |
| Urea | 2.5 bags | 115.00 | 287.00 |
| Fertilizer application | 10 Mandays | 11.1 | 111.00 |
| Fertilizer transport | | | 35.00 |
| **Goat Manure** | | | |
| Manure collection | 5 Mandays | 10 | 50 |
| Manure Application | 10 Mandays | 11.1 | 111 |
| Manure Transport | | | 200 |

1 bag = 50kg.

**Maize output price**

Price of maize grains (100 kg) = GH¢130.00

Price of maize / kg = GH¢ 1.30 for all varieties and in all the agro–ecological zones.