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DEPARTMENT OF MATERIALS ENGINEERING

SUSTAINABILITY ASSESSMENT OF RAINFED MAIZE PRODUCTION SYSTEMS IN THE TANO NORTH DISTRICT

BY

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DECLARATION

I hereby declare that this thesis is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree by the university or any other university, except where due acknowledgment has been made in the context.

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ABSTRACT

Maize production in Ghana is mostly done under rainfed conditions in almost all the agro-ecological zones, predominantly by smallholder farmers. This is characterized by low yield of 1.88 t/ha as compared to the potential yields of 5.5 t/ha as reported by the Crops Research Institute (CRI), Kumasi, Ghana. In order to improve and sustain yield in the wake of climate variability and change, rainfed maize production practices and sustainability need to be assessed. However, sustainable maize production is not only a question of yields but also of protecting the environmental resource base through suitable and environmental conscious agronomic practices, inputs use and management of agro-chemicals. Data on maize production practices were obtained from smallholder farmers and MoFA officials in the Tano North District. Factors such as land preparation methods, maize variety, planting methods, weed control, disease and pest control, fertilizer type and application, yield, extension and rainfall characteristics that affect maize production were assessed. Additionally, rainfall data from 1993-2012 were obtained from the Ghana Meteorological Agency, Sunyani. The data obtained were analysed to obtain percentage response, frequency, and mean; and using simulated rainfall data to obtain onset, cessation and length of the rainy season. The results showed that the current constraints to maize production sustainability include the practice of traditional farming methods such as land preparation method (slash and burn), poor seed source (use of seeds from farmer's own farm) and selection, and planting method and tools used; pest and disease prevalence; lack of financial and input support; rainfall variation (late or early rainfall onset); poor access to extension and land acquisition. Comprehensive government policy on agriculture (particularly on maize production), yield gap analysis for maize, and further research into farmers' accessibility of available extension are recommended to improve and sustain maize production in the study area.

DEDICATION

This work is dedicated to Christ Jesus Whom I trust and worship, my late mother, Madam Annah Yaa Yeboaa and my late former academic supervisor, Dr. Emmanuel Ofori, formerly of Agricultural Engineering Department, KNUST, may their souls rest in perfect peace.

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CHAPTER ONE

INTRODUCTION

Maize is the world's third most important crop after rice and wheat. About half of this is grown in developing countries (Ofori and Kyei-Baffour, 2006). Today, maize is Ghana's most important cereal crop. It is grown by the vast majority of rural households in all parts of the country except for the Sudan Savannah zone of the far north. As in other African countries, in Ghana, maize is cultivated by both men and women. Maize cropping systems and production technologies vary among the four agro-ecological zones in which significant amounts of maize are cultivated (Morris *et al.,* 2003).

According to statistics, the area annually planted to maize in Ghana averaged about 650,000 ha (Morris *et al.,* 2003). Maize grown in Ghana is mostly cultivated in association with other crops, particularly in the coastal savannah and forest zones, and therefore planting densities are generally low. Average grain yields of maize are correspondingly modest, averaging less than 2 t/ha. Total annual maize production is currently estimated at just over one million tonnes. The two key determinants of production (area planted and yield) have increased over the years, although the upward trends have been characterized by high year-to-year variability typical of rainfed crops. Following a pattern that has been observed throughout West Africa, the transition zone has become increasingly important for maize production. The rising importance of the transition zone as a source of maize supply can be attributed to a combination of factors, including the presence of favourable agro-ecological conditions, availability of improved production technology, a relative abundance of underutilized land and a well-developed road transport system (Morris *et al.,* 2003).

The relative abundance of arable land in the transition zone has attracted many migrant farmers, particularly from the north of the country, who moved to the zone to pursue commercial food farming.

The Tano North District (TND) is one of the major maize producing centres in Ghana. It lies in the semi-equatorial zone which experiences two (2) rainy seasons (major and minor). The mean annual rainfall is between 1,250 mm and 1,800 mm. The District lies in the moist semi-deciduous forest zones of Ghana and has a gross forest area of 157.45 km^2. The District has two forest reserves namely; Apape and Bosomkese forest reserves. There exists a vast expanse of guinea savannah vegetation found in areas such as Subriso, Mankranho, Sukuumu, and Adrobaa where maize production is predominant. Generally, the soils in the District are fertile. The abundant arable land found in the District is favourable for the cultivation of a wide range of food and cash crops (Ghana Districts, 2006).

In developing countries like Ghana, maize flour is a staple food for the people and its stalks provide dry season feed for livestock and soil mulch where it is in abundance. Diversified uses of maize worldwide include: maize grain; starch products; corn oil; baby foods; and popcorn. Maize can be classified on the basis of its protein content and hardness of the kernel. These include popcorn, flint, flour, Indian and sweet corn (Mauricio, 2000).

Climate is interrelated with other production factors and should be understood either as a resource to be managed or a factor that needs to be manipulated. Sustainable use of soil, capital and labour should be balanced with the use of climate and weather information. The response of maize crop to climate depends on the physiological make-up of the hybrid/variety being grown. Yield differences are the result of the genetic composition of the hybrid, the environmental conditions under which the crop is grown, and the degree of pest infestation (diseases, insects and weeds) (Ofori and Kyei-Baffour, 2006).

Maize production gains, achieved in Sub-Saharan Africa is through smallholder farmers adoption of improved seed and fertilizer during the 1980s were driven in part by the appropriateness of the technologies themselves and in part by state policies that encouraged their use through supporting markets and prices. Although these policies successfully promoted maize production in many countries, they imposed massive costs on national treasuries and contributed to the fiscal crises that most African governments experienced during the 1980s and early 1990s (Melinda *et al.,* 2011).

Maize currently covers 25 M ha in Sub-Saharan Africa, largely in smallholder systems that produced 38 M in 2005-2008, primarily for food (Melinda *et al.,* 2011). During the same period, maize represented an average of 27 % of cereal area, 34 % of cereal production and 8 % of the value of all primary crop production. This includes estimated area and production of green maize, which is highly valued as the harvest approaches the end of the - hunger season (Melinda *et al.,* 2011).

The potential for expanding maize production in Sub-Saharan Africa is huge. Even after excluding protected and forested areas, an estimated 88 M ha of land that is not yet planted to maize is suited to the crop. Worldwide, this amount is equivalent to four times the area now planted to maize and over half of the additional land area that is suitable for maize (Melinda *et al.,* 2011).

However, maize producers in these regions are often far from population centres with the markets and financial services that are conducive for technical change. Physical access to markets is far more restricted for farmers in Sub-Saharan Africa than for farmers in other regions of the developing rural world. Only a quarter of farmers in Sub-Saharan Africa are within 2 hours of markets by motorized transport, as compared to nearly half of farmers in Asia and the Pacific, and 43 % for the developing rural world. Of course, most rural people in Sub-Saharan Africa have no access to motorized transport, so these figures understate the magnitude of the problem (Melinda *et al.,* 2011).

Urban populations are growing at over 4 % per year in Sub-Saharan Africa compared to less than 1% among rural populations. To feed urban populations, especially in coastal cities, maize imports would have been much larger but for rising imports of wheat and rice. The consumption shares of wheat and rice in urban areas are growing rapidly even in areas where maize has long been the primary staple crop, reflecting the overall decline in maize self-sufficiency in these countries as well as a shift in urban preferences towards convenience staples such as wheat and rice (Jayne *et al.,* 2010).

Maize is a cross-pollinating crop, therefore a field of maize that is harvested and replanted will result in maize plants that differ from the preceding generation and from each other. Improved, open-pollinated varieties quickly lose their identity unless seed is frequently replaced. At the same time, cross-pollination enables breeders to exploit-hybrid vigour. The most rapid genetic improvements in cereals have been realized with hybrids in temperate maize (Fischer *et al.,* 2009). Provided that farmers replace the seed each season, yield advantages of hybrids can be substantial (Melinda *et al.,* 2011).

Maize is also photosensitive, yet it is grown over a wider range of altitudes and latitudes than any other food crop, under temperatures ranging from cool to very hot, on wet to semi-arid lands, and in many different types of soil. Environmental heterogeneity leads to continual interaction of genotype with environment and the formation of new maize types in farmers' fields through natural outcrossing and farmer selection. Well-adapted germplasm is highly specific to location. Thus, noteworthy advances in temperate maize among industrialized countries cannot be transferred to tropical environments of developing countries, and progress achieved in one tropical environment cannot be easily replicated in another (Melinda *et al*, 2011).

Sustainable agriculture according to Melinda *et al.* (2011) utilizes, "integrated systems of agriculture with production less dependent on high inputs of energy and synthetic chemical and more management–intensive than conventional monocultural systems. These systems maintain productivity and net incomes for farmers, are ecologically desirable, and protect the environment".

It is a system in which resources are kept in balance through conservation, recycling and/or renewal; practices that preserve agricultural resources and prevent environmental damage to the farm and offsite land, water and air; production, profit, and incentives remain at acceptable levels; and the system works in concert with socio-economic realities (Melinda *et al.,* 2011).

Maize is a heavy consumer of fertilizer, leading fertilizer demand in industrialized countries among major cereals, and the second most heavily fertilized crop on a global scale, after potatoes (Heisey and Norton, 2007). Farmers grow improved varieties without fertilizer in many areas of Africa, especially in marginal areas, such as the drier zones of Kenya and Zimbabwe, but also some relatively favoured areas, such as Ghana. Higher adoption rates for improved seed than fertilizer reflect the high costs of fertilizer in Africa, lack of input availability, and farmers' cash constraints.

Even where fertilizer is used, it is often used inefficiently (Heisey and Norton, 2007). A single recommendation is provided for wide areas, which does not account for the diversity of smallholder situations and the acute cash constraints under which they operate (Heisey and Norton, 2007). Extension has been the driving force behind the diffusion of improved maize technology to smallholders in all the countries that have experienced wide uptake of improved maize technologies (Melinda *et al.,* 2011).

Maize remains the most important food security crop for millions of rural households, chronic food insecurity persists even where progress in maize production has been achieved (Larson *et al.,* 2010). The fact that domestic maize production cannot keep up with the food requirements of expanding urban populations, African smallholders are generally competitive in maize production, at least with imports, and import substitution and integrated regional markets provide ready markets for greater maize production. Demand for maize to feed livestock is expected to grow rapidly; further taxing food supplies (Larson *et al.,* 2010).

Ghana also has large areas of low population density that are suitable for expanding maize production and it is therefore not surprising that intensification technologies have not yet been adopted, given relative land abundance. The savanna adoption of labour-saving technologies together with sustainable soil management practices will be the key to expanding the area under maize production (World Bank, 2009). Most of these areas are relatively remote and appropriate public investments in infrastructure and technology, combined with private investment in commercial farming, offer the opportunity for Ghana to be a major exporter of maize in the future.

Although Ghana’s natural conditions for agriculture are advantageous, the country remains highly dependent on food imports. According to the Ministry of Food and

Agriculture (MoFA), Ghana's agricultural production currently meets only half of domestic cereal consumption. Self-sufficiency is achieved only in starchy staples such as cassava, yam and plantain, while rice and maize production fell far below demand (EIU, 2007).

There are various reasons why Ghana's food crop yield remains below potential. Agriculture is largely rainfed, with traditional systems of farming still prevailing in most parts of the country. Production levels vary according to weather conditions since Ghana's irrigation potential remains almost untapped. Poor technology and small production units prohibit economies of scale and lead to sub-optimal yields. For example, maize is produced at a third of its potential yield per hectare (OECD, 2008). The maize production sector also suffers from public underinvestment.

1.1 Problem Statement

The population in sub-Saharan Africa is predicted to increase to over one billion by 2025. In order to meet the food requirements of the increased population and achieve food security by 2015, agricultural production would need to increase by 6% per annum (Inocencio *et al.*, 2003). These advances will need to be made with the added constraint of climate variability and change. Climate change will potentially affect the lives of people in many ways, particularly in Ghana where many poor smallholder farmers depend on agriculture for their livelihood with very limited alternatives of earning a living (Jones and Thornton, 2003).

In the developing world like Ghana, most farmers have to accept low yields as they are unable to consider the use of improved production methods, because they operate at subsistence levels. The problem of disease and pest control among different production levels is particularly acute on the small-scale, resource-poor systems under which maize is typically grown in tropical regions of the world (Ofori and Kyei-Baffour, 2006).

In areas where improved maize varieties have been widely adopted, genetic yield gains are dampened by the use of poor management practices. Use of fertilizers and other crop management practices remain limited. The understanding of climate variability and change effect on maize production is limited. Combined with soil nutrient mining and degradation, these poses fundamental challenges to Ghana‘s rainfed maize production system and its sustainability.

Maize is Ghana’s number one staple crop followed by rice, and domestic demand for both is growing. Between 2010 and 2015, maize demand was projected to grow at a compound annual growth of 2.6 %. The country is not self-sufficient in this most important staple crop, as Ghana has experiences average shortfalls in domestic maize supplies of 12 % in recent years. Therefore, the Government of Ghana has interest in increasing production of this key staple food to meet the country’s growing demand for maize and to improve food security. Maize production is currently dominated by smallholder farmers who rely on rainfed conditions with limited use of improved seeds, fertilizer, mechanization, post-harvest facilities and climate information. As a result, average yields in Ghana are well below attainable levels and post-harvest losses are high (Jayne *et al.,* 2010). Investors in commercial farming have the opportunity to realize yields per hectare of 5.0-5.5 tonnes in maize, 4.5 tonnes using the best sustainable agricultural practices in order to capitalize on the large and growing demand for this critical staple crop in Ghana (Jayne *et al.*, 2010).

In most areas like Tano North District, access to land has become so constrained that surplus maize production is unattainable for many smallholder farmers even with successful adoption of seed and fertilizer technologies. A strategy to diversify maize production systems could provide higher returns to scarce land and improve food security, provided that retail maize markets are dependable.

1.2 Justification

In the tropics and subtropics most maize is grown by small-scale farmers, generally for subsistence as part of agricultural systems that feature several crops and sometimes livestock production. The system often lacks inputs such as fertilizer, improved seed, irrigation and labour. In most developing countries, there is very little purchased input for the cropping system and farmers essentially depends on the natural resource base. Rainfall is the single most important natural resource input under this form of cropping. Increasing population pressure has resulted in an intensive land use. Thus, nutrients and organic matter in the soil have been depleted and crop yields have steadily decreased. To increase production, it will be necessary to replenish soil nutrients and optimise the use of other resources such as seed, water, capital, transportation, labour, extension services among others. Land use intensification is only feasible if nutrients depleted during cultivation are replenished. Inorganic fertilizer use in Ghana is generally limited by the lack of financial resources for the farmers (Ofori and Kyei-Baffour, 2006).

The need to improve smallholder rainfed maize production in a sustainable manner is important in the Tano North District, as maize is a staple food to the rural population. Smallholder maize production is often characterised by low yields, which are often significantly lower than the potential for the land. However, sustainable maize production is not only a question of yields, but also protection of the environmental resource base, social welfare and the livelihoods of farmers. Sustainability for the smallholder farmer raises questions of household food security, farmer and community well-being as well as agro-ecosystem integrity.

1.3 Research Objectives

The research had its main objective as assessing the sustainability rainfed maize production practices. Specifically, the study sought to achieve the following objectives:

- To assess the current rainfed maize production practices in the Tano North District area

- To assess how current rainfed maize production practices affect environmental sustainability in the District

- To assess how rainfall pattern and characteristics affect rainfed maize production in the District and

- To assess the perception of the Ministry of Food and Agriculture staff on sustainable rainfed maize production in the District.

1.4 Research Questions

The study therefore set out to find answers to the following relevant questions:

- What are the current rainfed maize production practices by farmers in the Tano North District?

- Are the maize farming practices in the Tano North District environmentally sustainable?

- Are rainfall pattern and characteristics in the District conducive for sustainable maize production?

- What are the perceptions of the Ministry of Food and Agriculture staff on sustainable rainfed maize production in the District?

1.5 Organization of the thesis

The thesis is organized into five chapters as follows: Chapter One is made up of five sections. These include the introduction, problem statement, justification, objectives and the research questions of the study. Chapter Two is the literature review of the study. It is written under the following headings: Overview of Maize Production; Maize production in Ghana; Maize Variety and Growth Characteristics; Maize Crop Management Practices; Climate Variability and Maize Production; Soil Fertility and Maize Production; and Soil Water Management for Maize Production. Materials and methods of data collection are explained in Chapter Three. In this chapter also, the various methods employed in analyzing the data are described. The Fourth Chapter presents and discusses the results of the study on the sustainability of the rainfed maize production in the Tano North District. The data collected were statistically analyzed for significant conclusions to be drawn in the next chapter. Chapter Five comprises conclusions to the performed analytical steps and makes recommendations (to farmers, institutions and government that the project will be of use to) for future research work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Maize Botany, Types, Yield and Sustainability

2.1.1 Origin and distribution of maize

Maize is a direct domestication of a Mexican wild annual grass strain of teosinate (*Zea mays* parviglumis) which is native to the Balsas River valley of Southern Mexico (Guat and Doebley, 1997). The 12% of maize genetic material is obtained from *Zea mays* mexicana through introgression; it is derived from hybridization between a small domesticated maize (a slightly changed form of wild maize) and teosinate of section Luxuriantes, either Z. luxurians or Z. diploperennis. Recent genetic evidence suggests that maize production occurred 9000 years ago in Central Mexico.

Maize, the American Indian word for corn, literally means "that which sustains life". Though, maize is grown throughout the country, the forest – savannah transition zone is the suitable agro-ecological region for maize. This has bimodal rainfall pattern and as a result has two cropping seasons. Maize is notably grown by smallholder farmers, who targets both local and foreign markets. Maize cultivation is therefore mainly dependent on rainfall. It is either grown as a single crop as in mono-cropping or intercropped with root and tuber crops or legumes (Dankyi, 2005).

Maize is the highest source of carbohydrate in Ghana, and it is cultivated in almost all the regions across the nation. It is processed into varying dishes among the different ethnic groups. Traditionally meals like *banku, kenkey, akple, wokpl, obloyo, ekpegwemi,* porridge and others can be prepared from processed maize dough. Other uses of maize-worldwide include: maize grain, starch products, corn oil, baby foods, popcorn, maize-based food items, maize flour, forage for animals, maize stalks providing dry season feed for farm animals, maize silage for winter animal feed in cold temperate regions, and maize stalks as a soil mulch where it is in abundance. Maize grain is also used as feed for livestock. Maize is classified on the basis of its protein content and hardness of the kernel.

In industrialized countries maize is largely used as livestock feed and as raw materials for industrial products, thus, processing (breakfast cereals, corn chips, grits and flour), industrial starch and popcorn, while it is mainly used for human consumption in low income countries.

Ghanaians consume maize as a starchy base in a wide variety of porridges, pastes, grits, and beer. Green maize (fresh on the cob) is eaten parched, baked, roasted or boiled and plays an important role in filling the hunger gap after the dry season. However, the yields are low, fluctuating around 1.0 t/ha. Low yields in maize production in Ghana have resulted due to heavy pre-and post-harvest losses caused by diseases, weeds and pests (Ofori and Kyei-Baffour, 2006).

With appropriate crop and land husbandry practices (management practices) and accurate knowledge and information on the rainfall pattern in the Tano North District, the farmer will be able to maximize the yield with reduced risk of crop failure due to the irregular rainfall pattern.

Maize acreage in Ghana in 2006 was around 750, 000 ha but in the year 2004, the area cultivated was 936,000 ha. There was a decrease of about 20 % of the area under cultivation due to inadequate rainfall distribution and poor management of crops and equipment for production. According to FAO data, the area planted to maize in West and Central Africa increased from 3.2 million ha in 1961 to 8.9 million ha in 2006.

This expansion of land area assigned to maize increased production from 2.4 million metric tonnes in 1961 to 10.6 million metric tonnes in 2005. While the average yield of maize in developed countries can reach up to 8.6 t/ha, production per hectare is still very low (1.3 t/ha) in Ghana (FAO, 2005).

2.1.2 Botany of maize

Salvador (1997) described maize as a tall, determinate annual plant producing large, narrow, opposite leaves, borne alternatively along the length of a solid stem. Singh (1990) reported that, the leaves are rough, hairy and the outstanding feature of the crop is the separation of the sexes into different parts on the same plant. Ghosh (2004) also describe the male flowers as the tassels and the female flowers as the spikes on a modified lateral branch called the “cob” or “ear”. The seed contains two structures, which are the germ from which new plants develop and the endosperm which serve as source of food for germinating seed. Maize being a cross-pollinated plant has broad morphological variability as a result. The kernels vary in colour ranging from white to yellow, red and blue. Maize is classified into 5 types based on their endosperm colour and texture (Salvador, 1997).

2.1.3 Types of maize

i. Dent corn (*Zea mays* var indentata)

The seed has a cap of soft starch that shrinks upon drying and form a dent at the top of the kernel. It is the highest yielding.

ii. Flint corn (*Zea mays* var indurate)

The kernel is hard and smooth. It is an indigenous variety in Africa which is more resistant to storage insects like weevil than the dent and floury corn.

iii. Floury corn (*Zea mays* var amylaceae)

The seed has a soft starch and is prone to storage insects and breakages than the harder types.

iv. Sweet corn (*Zea mays* var saccharata)

The seed is yellow in colour. It has a higher sugar content than any ordinary maize. It is also consumed in the immature stage when only about one-third of the potential grain yield has been accumulated. It is more prone to insect damage especially on the ears.

v. Popcorn (*Zea mays* var evareta)

The endosperm surrounds a small area of soft starch. This soft starch contains a significant amount of moisture which when heated generates steam and pressure resulting in swelling and bursting giving a pop sound.

2.1.4 Maize gap and yield potential

In the developing world, most farmers have to accept low yields because they are unable to consider the use of improved production methods, because they operate at small scale subsistence levels, yield gap analyses will draw farmers' attention to lost production potential under the prevailing climatic conditions in their respective environments and what production potential under the prevailing climatic conditions in their respective environments and what production practices (soil fertility, agronomic, cultivar selection, etc.) need to be improved. Yield potential refers to the highest yield achievable on farmers' fields – with the use of improved seed (high yield, tolerance to diseases and pests) appropriate levels of nutrients, water and weed control. Yield differences among regions as shown in Table 2.1 provides the incentive to manoeuvre toward yield improvement. According to Ofori *et al*. (2004) the difference between the actual and potential yield of typical maize variety grown, during the major cropping season (April through July), on a farm in Ghana over a 9-year period, was just over 5 t/ha (thus actual yield varied from 0.9 to 1.4 t/ha and the potential for that season should have been 5.5 t/ha). The April-July rainfall varied from 570 to 790 mm over this 9-year period.

Table 2.1: Yield potential (t/ha) relative to current yield in developing world

Ecological environment	Highland/Transitional	Midaltitude/Subtropical	Tropical lowland
East & Southeast Asia	5.0 (3.5)	8.0 (3.0)	5.5 (2.2)
South Asia	5.0 (0.7)	7.0 (2.6)	4.5 (1.4)
West Asia/North Africa	-	4.5 (3.2)	-
Sub-Saharan Africa	5.0 (0.6)	7.0 (2.5)	4.5 (0.7)
Latin American/Caribean	6.0 (1.1)	10.0 (4.0)	5.0 (1.5)

Source: Pradhu and Shivaji, 2000.

2.1.5 Sustainability in agricultural systems

Sustainability is a generational requirement to manage the resource base such that the average quality of life enjoying can potentially be shared by all future generations (Feenstra, 2002). Today, agricultural sustainability centres on the need to develop technologies and practices that: do not have adverse effects on the environment (partly because the environment is an important asset for farming), are accessible to and effective for farmers, and lead to both improvements in food productivity and have positive side effects on environmental goods and services (Pretty, 2002).

Sustainability in agricultural systems incorporate concepts of resilience (the capacity of systems to buffer shocks and stresses) and persistence (the capacity of systems to continue over long periods), that address economic, social and environmental outcomes (Pretty, 2002). Agricultural sustainability focuses on both genotype improvements through the full range of modern biological approaches and improved understanding of the benefits of ecological and agronomic management, manipulation and redesign (Pretty, 2003).

Agricultural systems at all levels rely on the value of services flowing from the total stock of assets that they influence and control (Worster, 1993). The five assets/capitals are defined in the following ways:

i. *Natural capital* produces environmental goods and services. They are the source of food (both farmed and harvested or caught from the wild), wood and fibre; water supply and regulation; treatment, assimilation and decomposition of wastes; nutrient cycling and fixation; soil formation; biological control of pests; climate regulation; wildlife habitats; storm protection and flood control; carbon sequestration; pollination; and recreation and leisure (MEA, 2005).
ii. *Social capital* yields a flow of mutually beneficial collective action, contributing to the cohesiveness of people in their societies. They include norms, values and attitudes that predispose people to cooperate; relations of trust, reciprocity and obligations; and common rules and sanctions mutually agreed or handed down. These are connected and structured in networks and groups (Pretty, 2003).
iii. *Human capital* is the total capability residing in individuals, based on their stock of knowledge skills, health and nutrition. It is enhanced by access to services such as schools, medical services and adult training. People's productivity is increased by their capacity to interact with productive

technologies and other people. Leadership and organizational skills are particularly important in making other resources more valuable (MEA, 2005).

iv. *Physical capital* is the store of human-made material resources and comprises buildings, such as housing and factories, market infrastructure, irrigation works, roads and bridges, tools and tractors, communications, and energy and transportation systems, which make labour more productive (Pretty, 2002).

v. *Financial capital* is more of an accounting concept and serves as a facilitating role rather than as a source of productivity. It represents accumulated claims on goods and services, built up through financial systems that gather savings and issue credit such as pensions, remittances, welfare payments, grants and subsidies (MEA, 2005).

Sustainable agriculture outcomes can be positive for food productivity, reduced pesticide use and carbon balances. Significant challenges, however, remain to develop national and international policies to support the wider emergence of more sustainable forms of agricultural production across both industrialized and developing countries (MEA, 2005).

2.2 Maize Characteristics and Production in Ghana

2.2.1 Maize variety and growth characteristics

The crop growth follows a specific pattern irrespective of the environmental conditions. Crop growth passes through different stages of growth, that is, the initial, crop development, mid-season and late season stages with each stage having its own characteristics, material and husbandry needs. These stages and their characteristics must be known to the farmer for effective use in production decision making. Days to silking maturity determines the critical period of maize plant (Table 2.2). That is the period during which soil moisture is critical. The crop yield or quality resulting from drought stress depends on the stage of crop development (Ofori *et al.,* 2004). Generally; early hybrids require higher plant densities for maximum yield than late hybrids (Tollenaar, 1992). The reason being that early hybrids like '*Dorke*' SR and '*Dodzie*' are normally smaller in height, produce less leaves, have lower leaf area index that produces maximum interception of solar radiation. Varieties could be selected based on the following:

- Days to silking to coincide with the time of high rainfall dependability
- Days to maturity that will suitably fit into a season and
- Level of drought tolerance.

I. Maize variety suitability

Maize varieties have different way of planting, different stages they endure before maturity and different critical stages like any other crop. The varieties planted in Ghana are the full season, the medium season and the early season, according to their days of maturation. The full season matures between 115 – 120 days; the medium season matures between 105 – 110 days and the early season between 90 – 95 days. The full season varieties normally have the highest yield potential to be realized. The early and extra – early maturing varieties should be planted at higher densities. Timely planting of maize as much as possible over the years has established the following advantages (CRI, 2005) (Table 2.3):

- Higher yields with lower incidence of diseases
- Benefit from higher soil fertility and
- Lower incidence of bird and rodent damage and more days of sunlight.

Table 2.2: Recommended varieties of maize, their days to mid-silking and maturation

Variety	Year of Release	Variety Type	Days to Mid-Silking	Days to Maturity	Grain Yield (t/ha)
Nyankariwana I	1954	NA	NA	100	2.5
Nyankariwana II	1954	NA	NA	100	2.5
GSI GSII GSIII	1955-1961	NA	NA	120	3.5
Mexican 17	1961	NA	NA	110	3.5
Composite 2	1968	NA	NA	120	4.0
Composite W	1972	NA	NA	120	5.0
Composite 4	1972	NA	NA	120	5.0
La posta CRI	1972	NA	NA	120	5.5
Golden Crystal	1972,1984	NA	NA	110	5.0
Satifa – 2	1984	NA	NA	95	4.0
Dobidi	1984	Late	55	120	5.5
Abruotia	1984	NA	NA	105	4.5
Okomasa	1988	Late	55	120	6.0
Abeleechi	1990	Medium	53	105	5.0
Dorke SR	1990	Early	52	95	4.5
Obatanpa	1992	Medium	55	105	5.5
Dodzi	1997	Extra-early	48	80	4.0
Dadaba	1997	Medium	51	105	7.5
Mamaba	1997	Medium	51	105	7.5
CIDA – ba	1997	NA	54	105	7.5
Golden Jubilee	2007	Medium	50	110	5.0
Akposoe	2007	Extra-early	45	85	3.5

Source: CRI, 2005.

Maize tolerates dry period better during the first 3-4 weeks of growth. It is when drought stress occurs at flowering time that the yield can be reduced to zero (CRI, 2005).

Table 2.3: Planting period suitable for different maize varieties

Major season			
		Recommended variety	
Location	Planting period	Early planting	Late planting
Forest	Early March-end of April	*Okomasa, Mamaba, Obatanpa*	*Okomasa, Abeleechi, Obatanpa*
Transition	Mid March-end of April	*Okomasa, Mamaba, Obatanpa*	*Okomasa, Abeleechi, Obatanpa*
Coastal savannah	Mid March-end of April	*Okomasa, Mamaba*	*Abeleechi, Dorke-*SR
Guinea savannah	Mid March-end of June	*Okomasa, Mamaba, Obatanpa*	*Okomasa, Abeleechi, Mamaba, Dorke-*SR
Minor season			
Location	Planting period	Recommended variety	
		Early planting	Late planting
Forest	Mid July-early September	*Mamaba, Obatanpa*	*Obatanpa, Abeleechi, Mamaba, Dorke-SR*
Transition	Mid July-early September	*Mamaba, Obatanpa*	*Obatanpa, Abeleechi, Mamaba, Dorke-SR*
Coastal savannah	Mid July-early August	*Mamaba, Obatanpa, Dorke-SR*	*NA*

Source: CRI, 2005

II. Variety selection

Farmer’s select the varieties that are most suitable for the climate region in which the farm is located. In tropical regions of the world, it is the onset of the rainy season that dictates the selection and optimum time to plant maize varieties. They are selected to match the anthesis period to when the soil moisture is likely to be most adequate, unless there is water available to irrigate the crop when necessary.

2.2.2 The maize economy of Ghana

Maize has been cultivated in Ghana for several hundred years. After being introduced in the late 16th century by the Portuguese, it soon established itself as an important food crop in the southern part of the country. Very early on, maize also attracted the attention of commercial farmers, although it never achieved the economic importance of traditional plantation crops, such as oil palm and cocoa. After a while, the overriding demand to supply and the eroding profitability of many plantation crops (attributable mainly to increasing disease problem, deforestation and natural resource degradation) served to strengthen interest in commercial food crops, including maize (Morris *et al.*, 1999).

What distinguishes Ghana from many other countries, however, is that Ghanaian women frequently manage their own maize fields, contribute an important proportion of the overall labour requirements, and exercise complete discretion over the disposal of the harvest (Morris *et al.*, 2003).

2.2.3 Maize cropping in the four agro-ecological zones of Ghana

Maize cropping systems and production technologies vary across the four agro-ecological zones in which significant amount of maize are cultivated (Morris *et al.*, 1999).

Coastal savannah zone

Coastal savannah zone includes a narrow belt of savannah that runs along the coast, widening toward the east of the country. Farmers in this zone grow maize and often intercrop with cassava. Annual rainfall, which is bimodally distributed, totals only 800 mm, so most maize is planted following the onset of the major rains that begins in March. Soils are generally light in texture and low in fertility, so productivity is low.

Forest agro-ecological zone

Immediately inland from the coastal savannah lays the forest zone. Most of Ghana's forest is semi-deciduous, with a small proportion of high rain forest remaining only in the south-western part of the country. Maize in the forest zone is grown in scattered plots, usually intercropped with cassava, plantain, and /or cocoyam as part of a bush fallow system. Although some maize is consumed in the forest zone, it is not a leading food staple and much of the crop is sold. Annual rainfall in the forest zone averages about 1,500 mm; maize is planted both in the major and the minor rainy seasons.

Transition agro-ecological zone

Moving further north, the forest zone gradually gives way to the transition zone. The exact boundary between the two zones is subject to dispute, which is not surprising considering that the boundary area is characterized by a constantly changing patchwork of savannah and forest. The transition zone is an important region for commercial grain production. Much of the transition zone has deep, friable soils, and the relatively sparse tree cover allows for more continuous cultivation (and greater use of mechanized equipment). Rainfall is bimodally distributed and averages about 1,300 mm/y. Maize in the transition zone is planted in both the major and minor seasons, usually as a monocrop or in association with yam and/or cassava.

Guinea savannah agro-ecological zone

The Guinea savannah zone occupies most of the northern part of the country. Annual rainfall totals about 1,100 mm, falling in a single rainy season beginning in April or May. Sorghum and millet are the dominant cereals in the Guinea savannah, but maize grown in association with small grains, groundnut, and/or cowpea is also important. Maize is grown in permanently cultivated fields located close to homesteads, as well as in more distant plots under shifting cultivation (Morris *et al.*, 1999).

2.3 Maize Crop Management and Technology Transfer

Agronomic practices that will improve soil fertility and increase yield should be employed. These crop and land husbandry practices include:

a) Cultivation practices that will:
    - Destroy the seeds of various weeds
    - Encourage healthy plant growth and
    - Conserve soil moisture.

This can be achieved by mulching, residue management, no-till or zero tillage, reduced field traffic, organic matter addition, suitable fertilization rates based on proper soil assessments.

b) Integration of maize crop with suitable crops for:
    - Crop rotation
    - Mixed cropping and
    - Sequential cropping.

Suitable crops for crop rotation, mixed and sequential cropping should be carefully selected based on their effect on weed, pest and disease control and soil fertility. Various cultural practices are employed, ranging from land preparation methods, soil fertility management, soil and moisture conservation, control of disease, insect and weeds (Ofori *et al.*, 2004).

2.3.1 Control of crop pests and diseases

Crop infection and infestation by diseases, insects and weeds can significantly reduce yields in both temperate and tropical regions. Diseases are best controlled through maize breeding programmes that develop hybrids with resistance to such diseases as: leaf blights, root and stalk rots, rusts, and smuts. Maize diseases are usually not controlled by spraying with fungicide chemicals, except that seed is often treated before planting with a fungicide powder to control soil pathogens that damage the embryo before germination. Wet and cold soil (less than 10^{o}C) conditions at planting time are most favourable for these seed diseases (Ofori and Kyei-Baffour, 2006).

The problem of disease and pest control among different production levels is particularly acute in the small-holder, resource-poor systems under which maize is typically grown in tropical regions of the world. 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. Numerous species of weeds can infest maize crops and cause yield losses in both temperate and tropical regions. In temperate regions, most of the time weeds are controlled by herbicide application. Herbicides are often too expensive for farmers to use in tropical regions, so other cultural practices, such as crop rotation and hand cultivation, are used to control weed infestations. Weather conditions play a role too, but are not as critical as for herbicide application.

According to several studies around the world (James *et al.*, 2000; OMAFRA, 2002) as cited by Ofori and Kyei-Baffour (2006), the best time to minimize the effect of weeds on maize yields is within 4 to 8 weeks after planting when maize is in the 2 to 8 leaf stage. When weeds are controlled culturally during this initial period of maize growth, then shading by the crop is quite effective in controlling weed growth during the remaining time to maturity.

2.3.2 Soil condition and maize production

The soil's fertility needs to have an optimum balance of the three major nutrients, nitrogen, phosphorus and potassium, and the necessary micronutrients, such as boron, calcium, magnesium, manganese and molybdenum. The farmer should have the soils on his farm assessed for the three major nutrients every year or two to determine how much fertilizer should be added to maximize maize production. This is an important management practice in both temperate and tropical regions. The farmer should be aware of fertilization requirements and procedures with respect to the soil nutrient levels, the growth stage, the crop variety, the targeted yield and the agronomic practices (Ofori and Kyei-Baffour, 2006).

2.3.3 Soil fertility and nutrient depletion

The consequence of nutrient depletion can be categorized into on-farm and off-farm such as economic, social and environmental effects. A marked decline in crop productivity and food security are the main consequences of the policies that result in soil-fertility depletion in Africa. On-farm effects include less fodder for cattle, less fuel wood for cooking, and less crop residues and cattle manure to recycle nutrients. These effects often increase runoff and erosion losses because there is less plant cover to protect the soils. In sandy soils, the topsoil structure may collapse resulting in soil compaction or surface sealing (Sanchez *et al*., 1997).

Soil nutrient depletion lowers the returns to agricultural investment, which reduces non-farm incomes at the community level through multiplier effects (Delgado *et al*., 1994). Other consequences of depletion are decreased food security through lower production and resulting higher food prices, increased government expenditures on health, more famine relief, and reduced government revenue due to less taxes collected on agricultural goods.

The most important consequence of soil fertility depletion on social life is its link to lower employment and increased poverty which is responsible for majority of poor livelihood in rural areas in the tropics (World Bank, 1990). As long as returns to agriculture are limited by nutrient depletion, farm employment and spillover non-farm employment opportunities will remain low, sustaining severe poverty. But these externalities are not confined to rural communities, as poverty often pushes individuals and households into urban areas. The influx of rural migrants puts a greater strain on the limited urban infrastructure; and unemployment, crime, and political unrest sometimes result (Homer-Dixon *et al*., 1993).

This situation is typical in high potential areas of eastern and southern Africa particularly in Burundi, Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia as well as in low and high potential areas of West Africa (Sanchez *et al*., 1997).

Soil-fertility depletion also exacerbates several environmental problems at the national and global scales. Increased soil erosion, particularly in steep areas, causes more unwanted sedimentation, siltation of reservoirs and of coastal areas, and in some cases eutrophication of rivers and lakes. There is evidence of these processes occurring in some African rivers and lakes (Melack and Maclntyre, 1992), including Lake Victoria, where erosion from surrounding nutrient-depleted lands is widespread.

The loss of topsoil organic C associated with soil nutrient depletion results in additional CO_2 emissions to the atmosphere from decreasing soil and plant C stocks. Assuming a C/N ratio of 10:1 in soil organic matter (SOM), the average N depletion rate of 22 kg N ha^{-1} y^{-1} represents an average rate of C loss of 220 kg C ha^{-1} y^{-1} from 200 million ha of cultivated soils of Africa. Carbon loss is a reversible process in soils as long as their clay contents are not decreased by erosion. This C sequestration process is gradual (Sanchez *et al*., 1997) and definitely not instantaneous. Although it takes place primarily in the topsoil, it also can occur in the subsoil when deep-rooted grasses and trees are introduced in degraded lands (Fisher *et al*., 1994; Sanchez, 1995). The cry for increasing SOM in sandy soils, so often heard in West Africa, can only occur in nutrient-depleted soils, but never up to the levels found in high potential clayey soils. With these caveats in mind, decreased CO_2 emissions and increased C sequestration can be a positive environmental externality of replenishing soil fertility (Sanchez *et al*., 1997).

Soil-fertility depletion decreases above and below ground biodiversity and increases the encroachment of forests and woodlands in response to the need to clear additional land (Sanchez, 1995). This is particularly relevant to the Miombo woodlands of southern Africa and to the rainforest remnants in the Great Lakes region and in eastern Madagascar, both of which harbour unique animal biodiversity.

2.3.4 Soil water management for maize production

In order to maximize maize yields, soil moisture should be maintained above 50% of the available water capacity in the rooting depth of the soil profile throughout the growing season. This is not always possible in either temperate or tropical climatic regions as rainfall can be very late and random in some years. However, it is essential to at least have adequate soil moisture at the time of anthesis in order to have a full set of kernels on the ear at harvest time. In general, maize needs at least 500-700 mm of well-distributed rainfall during the growing season (CIMMYT, 2005) depending on the location.

2.3.5 Transfer of Improved Technology

This may take place through demonstrations on improved crop production technology and Integrated Pest Management training programmes, seed production programmes and provision of fungicides, herbicides, insecticides and other inputs. The maize technology transfer in the Ghana Grain Development Project was based on three types of activities (Morris *et al.*, 1999): building linkages between research and extension, providing support to extension activities and strengthening seed production activity. Available varieties are continually changing as new ones are being developed, so there is a need to have up-to-date varietal information. The choice of variety depends on market requirements, environmental conditions, socio-economic considerations, whether the crop is irrigated and the levels of disease and pest resistance required. For example, the State of Queensland (Department of Primary Industries and Fisheries (DPIF), 2004) gives recommendations on factors to be considered as a guide to the selection of maize variety. Time to flowering, cob height, husk cover, disease resistance, "standability", end use and isolation are mentioned. Hybrid selection should be understood by all and must also have socio-economic components. It is necessary to develop suitable characterization methods for all hybrids that will make the selection process much easier and convenient.

2.4 Climatic Conditions and Maize Production

Climate variability has been and continues to be, the principal source of fluctuations in global food production in countries of the developing world. Climate change refers to the increase of earth temperature due to the release of gases such as CO_2, CH_4, CFCs, N_2O and O_3 into the earth's atmosphere (Ofori and Kyei-Baffour, 2006).

Climate is one of the most important limiting factors for maize production in the tropics particularly rainfall. Climate is interrelated with other production factors and should be understood either as a resource to be managed or a factor that needs to be manipulated. Sustainable use of soil, capital and labour should be balanced with use of climate and weather information. The response of the maize crop to climate depends on the physiological makeup of the variety being grown. Yield differences are the result of the genetic composition of the hybrid, the environmental conditions under which the crop is grown, and the infestation by crop pests (diseases, insects and weeds). The final yield will depend on the following (Ofori and Kyei-Baffour, 2006):

- Variety selection
- Soil fertility
- Soil water and
- Control of crop pest.

2.4.1 Climate suitable for maize growth

The ideal depth for sowing is 5 - 7 cm (Arnon, 1975). Emergence of seed occurs within 4 to 5 days after planting. Fageria *et al*. (1997) reported that maize does well within a temperature range of 21-30 ºC. When temperatures are below optimum, 14 days or more may be required. During emergence, it requires an average temperature of 13 ºC and fails to mature when the temperature falls to 10 ºC (Tisdale *et al*., 1985). The optimum temperature for maize growth and development is 18 to 32 ºC, with temperatures of 35 ºC and above considered inhibitory. The optimum soil temperatures for germination and early seedling growth are 12 ºC or greater, and at tasselling 21 to 30 ºC is ideal (Belfield and Brown, 2008). It is practically grown in extremely divergent climatic conditions, viz temperate to tropical up to an altitude of over 2500 m. Maize requires deep and fertile soils which are rich in organic matter content and have a pH of 7.5 to 8.5 (Singh, 1991). The root system is generally shallow; hence plant depends on available moisture within the plough layer. Its average maturing period is relatively short and this makes it possible to grow at fairly high altitudes. However, long days prolong the duration of the vegetative phase (Aloyce *et al*., 2000). It is very sensitive to shading (Salvador, 1997) and according to Fageria *et al*. (1997), it is very sensitive to drought during the time of silk emergence.

2.4.2 Climate variability and maize cultivation

Africa is one of the most exposed continent to suffer the devastating effects of climate change and climate variability, with colossal economic impacts because it often lacks adaptive capacity. The African rain-fed agriculture is viewed by many observers to be the most vulnerable sector to climate variability and the potential impacts of climate change on agriculture are highly uncertain (IPCC, 2007). The report by World Meteorological Organization (WMO) (1996) revealed that the overall global warming is expected to add in one way or another to the difficulties of food production and scarcity. The report also stated that reduced availability of water resources would pose one of the greatest problems to agriculture and food production, especially in developing countries like Ghana.

Also IPCC (2007) reported that climate variability is likely to increase under global warming both in absolute and relative terms. Factors such as endemic poverty, bureaucracy, lack of physical and financial capital, frequent social unrest and ecosystem degradation contribute to Africa's vulnerability to climate variability. Almost 65% of the Ghanaian population is rural-based with livelihoods predominantly dependent on subsistence crop farming and/or livestock rearing. Over the past years, multiple interrelated factors such as small fragmented landholdings and minimal access to agricultural inputs, reduced employment opportunities, market inefficiencies and high HIV/AIDS prevalence have contributed to chronic food insecurity and gradually weakening livelihoods (IPCC, 2007).

In addition, the agricultural system is dominated by a single crop, which is maize, coupled with the extensive dependence on rain-fed agriculture which will further increase households' vulnerability due to erratic rainfall and weather variability. Minimal shocks to agriculture therefore have a profound impact on the ability of rural households, especially the chronically poor, to maintain their food security. Climate change and variability is clearly evident in Ghana as it manifests itself in various hydrological disasters.

2.4.3 Rainfall amount, intensity and duration

Rainfall is the source of the world's fresh - water supplies for cultivation. Knowing the nature and characteristics of rainfall will warrant the conceptualizing and prediction of its effect on runoff, infiltration, evapo-transpiration, soil moisture and water yield which affect maize production. Rainfall serves as a major component in the hydrologic cycle which is needed to solve problems in soil and water conservation management for maize cultivation. Therefore it is important to know not only the total average precipitation for a region, but also its seasonal periodicity and dependability both seasonal and annual.

The main characteristics of rainfall include the amount, frequency and intensity, which vary from time to time. Intensity and duration are usually inversely related, thus, high intensity storms are likely to be of short duration and low intensity storms can have a long duration which affects the quantity and quality of grain produced.

The most common historical rainfall data are daily total amounts at selected locations. Such data are obtained from a standard rain gauge (tube) which gives the depth of rainfall accumulated between observations. More important are data from a recording rain gauge which gives a record of accumulation as a function of time. Therefore, intensities can be determined from recording gauges. Traditional rain gauges use a mechanical weighing mechanism, while modern electronic units tend to digitally record the time when each ¼ mm accumulates.

2.4.4 Rainfall onset, cessation and length of the growing season

The schedule of agricultural activities, right from land preparation, through crop selection and planting, to the time of harvesting for a developing country like Ghana, is rainfall dependent. The assessment and prediction of the onset and cessation dates of the rainy season is therefore crucial to the success of agricultural activities in Ghana (Amekudzi *et al*., 2015). The onset of rainy season according to fuzzy- logic approach by Laux *et al*. (2008) is defined as:

- A total of at least 20 mm of rainfall are observed within a 5- day period
- The starting day and at least two other days in this 5 day period should be wet (at least 1 mm of rainfall recorded).
- No dry period of seven (7) or more consecutive days occurring in the following 30 days.

This is to avoid the false start owing to the variable nature of tropical rainfall. The false start is said to happen when rainfall meeting the chosen criterion is followed by a long dry spell (Laux *et al*., 2008). The dry spell is based on the break of several days between two successive rainfall events, which is the significant decrease in water availability that result in plant wilting and dying. The causes of such anomalies depend on the general and synoptic circulation pattern of the tropical atmosphere and its very important mechanism. Reduced rainfall, long and frequent dry spells can have significant effects on the growth and yields of some seasonal crops such as maize.

2.4.5 Water requirements for maize

Maize is grown over a wide range of climatic conditions, differing in distribution and quantity of seasonal rainfall. Besides, the crop is grown under irrigated and rain-fed conditions. Rain-fed maize production forms about 75% of agriculture in areas where the crop is the main source of food and income for the people (Rockström *et al.,* 2010)

Maize requires considerable moisture and warmth from germination to flowering. The most suitable temperature for germination is about 21^0C and for growth about 32^0C. Extremely high temperature and low humidity during flowering damage the foliage, desiccates the pollen and interferes with proper pollination, resulting in poor grain formation. Maize is very sensitive to waterlogging, particularly during its early stages of growth (FALC, 2006).

Though maize thrives best on soils having adequate moisture during the growing season, the crop tolerates dry periods, especially during the first three to four weeks of growth. In areas such as the semi-arid and dry sub-humid environments, including the coastal savannah environment, the amount of rainfall is not only the limiting factor of rain-fed maize production but also the erratic nature of rainfall (Asare *et al.*, 2011).

However, water stress occurring at different crop developmental stages could potentially limit biomass accumulation and consequently reduce grain yield of the maize crop. The extent of reduction in maize productivity depends not only on the severity of the water stress or drought but also on the stage of the crop development the crop tolerance to water stress/drought and the efficiency with which the maize crop uses available soil water for growth, biomass accumulation and yield production (Asare *et al.*, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

This study was conducted in the Tano North District in the Brong-Ahafo Region. The area was chosen because, it is one of the major maize producing centres in the region and the country as a whole. The Tano North District is one of the Twenty-two (22) administrative districts of the Brong-Ahafo Region of Ghana. It was carved out of the then Tano District in 2004 with its Administrative capital is Duayaw-Nkwanta. It shares boundaries with Offinso and Ahafo-Ano Districts both in the Ashanti Region in the North-East and South-West respectively. Other Districts that share boundaries with Tano North include Tano South in the South, Asutifi in the West and Sunyani Municipal in the North (Ghana Districts, 2006).

The District lies between longitude 7° 00’ 25’, latitude 1° 45’ W and 2° 15’ W with a total land area of 876 Km^2, constituting about 1.8% of the total land area of the Brong-Ahafo Region. The District lies in the moist Semi-Deciduous Forest zones of Ghana and has a gross forest area of 157.45 Km^2. The District has two forest reserves namely; Apape and Bosomkese forest reserves. There exists a vast expanse of Guinea Savannah vegetation found in areas such as Subriso, Mankranho, Sukuumu, Adrobaa where maize cultivation and cattle rearing are predominant. The vegetation cover and ecology of the district have been destroyed and altered respectively due to slash and burn farming practice, perennial bushfires and game hunter’s activities (MoFA, 2012). The Tano North District has a total population of 78,415 comprising 39,338 males and 39,077 females in 2010 according to the population and housing census (GSS, 2010). The district has a population growth rate of 2.4%.

The District lies in the semi-equatorial zone which experiences two (2) rainy seasons (major and minor). The major season is usually between March and July with June as the peak. The minor season is between August and November. The mean annual rainfall is between 1,250 mm and 1,800 mm. The dry season is quite severe and occurs from late November to February (MoFA, 2012). The weather is mostly sunny with mean monthly high temperatures of 21-30^{o}C during the day and night and relative humidity of 90-55%.

The geology of the District is basically made of the middle Precambrian formation. Most parts of the District are underlain by lower Birimian rocks with few areas such as Bosomkese and Kwannisa underlain by granite. The soil consists mainly of forest orchrosol. Generally, soils in the district are fertile (MoFA, 2012).

The abundant arable land found in the District is favourable for the cultivation of a wide range of food and cash crops. Agriculture is the main occupation in the District. It employs about 64.4% of the total active work force in the District (MoFA, 2012). The major food crops grown are maize, cassava, plantain, cocoyam and yam. Some of the cash crops cultivated include cocoa, coffee, oil palm and citrus. Apart from the food and cash crops cultivated, vegetables such as tomatoes, garden eggs, okra and pepper are grown in large quantities during the dry season.

As practiced in most parts of the country, chiefs, family heads and a few individuals act as custodians of all lands in the district. Within a family set-up, land is passed on from generation to generation and a family member is entitled to a portion of land which is also passed on to the next of kin. Settler farmers may acquire land for farming activities on agreed terms such as shared cropping or outright purchase (MoFA, 2012).

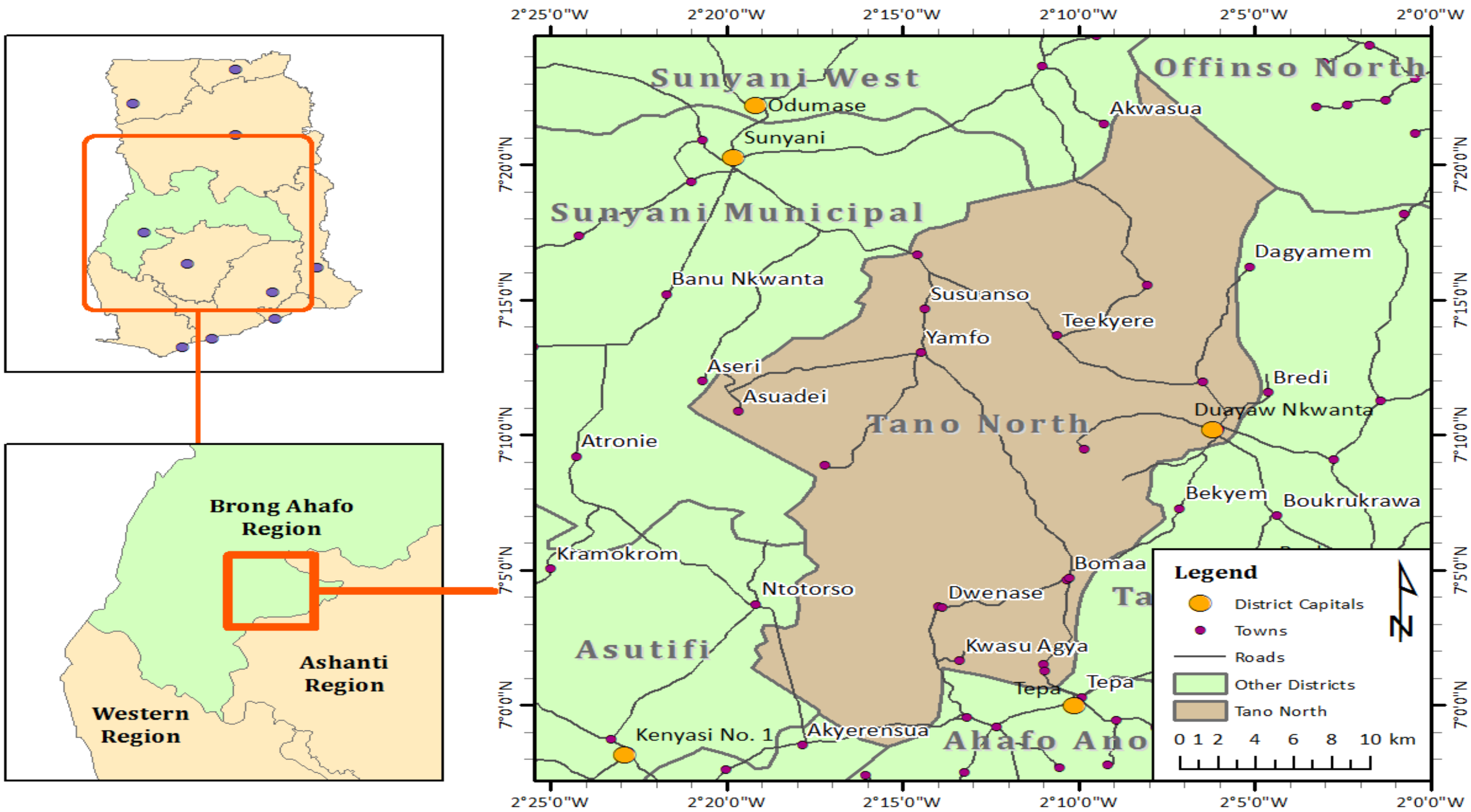

Figure 3.1 Map of Ghana showing the Tano North District

Source: Gaisie-Essilfie, 2014

3.2 Types of Data, Sources and Collection Procedure

Qualitative and quantitative data were collected from 200 maize farmers and 20 Ministry of Food and Agriculture (MoFA) officers, personal observations, one-on-one interviews, the administration of questionnaires (both structured and interview guides), were used in the collection of data. Random sampling method was exploited in selecting the maize farmers within the study area while MoFA staff were purposively sampled. Secondary rainfall data from 1993 to 2012 were collected from Ghana Meteorological Service, Sunyani and analysed.

The questionnaire were carefully designed to answer questions on the stakeholders' practices on the following

- Land preparation
- Crop variety type and planting pattern
- Weed control mechanism
- Pest and disease control mechanism
- Fertilizer type and application
- Yield, transportation, storage and income
- Rainfall pattern and general climatic variation
- Gender and land acquisition
- Financial and inputs support
- Crop residue management and
- Extension and other activities.

These items were chosen based on their effect or influence on maize yield and production.

Land Preparation

This was to determine from the stakeholders what indicators determine land preparation method in both farming seasons and the exact time of land preparation. The methods and tools used in tilling the soil and their effects on the environment were also asked for.

Seed Variety and Planting Pattern

This was to know the variety planted by stakeholders and reasons for the variety chosen, the maturity days of selected variety, the days to silking and tasselling of the variety. Also to know the planting period in both farming seasons, the planting pattern, the number of seeds planted per hill, the germination ability of the seed, the tool used in planting and the source of seeds were also found.

Weed Control Mechanism

This was to find out the weed management mechanism employed by farmers. Thus the number of times weed control is done, the method of controlling and what goes into weed control.

Pest and Disease Control Mechanism

Crop infection and infestation by diseases and insects can significantly reduce yields in tropical regions. This was to find out from stakeholders, their understanding of preventive measures for the insurgence of diseases and insects and the management of diseases and insects.

Fertilizer types and application

This was to find out from farmers their knowledge about fertilizer requirements and procedures with respect to the soil nutrient levels, growth stage, crop variety, targeted yield and the agronomic practices.

Farm size and yield

In Ghana, most farmers have low yield because they are unable to consider the use of improved production methods, since they operate at subsistence levels. The size and yield of cultivation is an important factor in assessing the sustainability of maize production. This was to find out farm sizes and the actual and potential yields.

Extension services, support to farmers and other activities

This was to find out the accessibility of agricultural extension services received by the stakeholders, the involvement of their farms in the form of on-farm trials, demonstrations and any other form of training the stakeholders' do acquire through either workshops or seminars.

3.3 Rainfall characteristics

Rainfall is a major factor that influences yields and sustains maize production over West Africa, especially Ghana. Information on the past and present onset and cessation of the rainy season served as a guide to maize farmers on when to start land preparation and planting to prevent crop failure. The 20 years rainfall data was analysed for the purpose.

3.4 Method of data analysis

In order to achieve the objectives of the study, the information gathered in the questionnaire and from the secondary data were coded and entered into a computer. The data was analysed using descriptive statistics (frequency, percentage response, means, graphs) with Microsoft Excel. The 5 – year moving average, anomaly of rainfall and growing season were determine. Also the rainfall data was analysed to obtain onset, cessation and length of the rainy season using GNU plotting tool (in Linux Operating System).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 General Characteristics of the Sampled Respondents

This chapter presents and discusses the results of the study on sustainability of the rainfed maize production in the Tano North District. The data collected were statistically analyzed for significant conclusions to be drawn in the next chapter.

Table 4.1: Gender distribution of respondents

Sex	Frequency	Percent (%)
Male	147	73.5
Female	53	26.5
Total	200	100

Table 4.1 shows 73.5% of respondents as male and 26.5% as female. Thus maize farming is dominated by male. This observation may be explained by a number of factors; among them are problems in land and other farming inputs acquisition, availability of time and money, and also for females ability to rub shoulders with their male counterparts due to natural and domestic obligations.

In a typical Ghanaian setting like the study area, it is evident that, due to natural and domestic responsibilities like child bearing and caring, cooking, washing, sweeping among others; females do not have time and strength to do some farming activities. These domestic obligations limit women and possibly cause gender disparity among maize farmers. According to Morris *et al.* (1999), Ghana maize is cultivated by both men and women. What distinguishes Ghana from many other countries, however, is that in Ghana women frequently manage their own maize fields, contribute an important proportion of the overall labour requirements, and exercises complete discretion over the disposal of the harvest.

Table 4.2: Educational distribution of respondents

Level	Frequency	Percent (%)
Tertiary	5	2.5
Post-Secondary	13	6.5
O'Level/SHS	29	14.5
MSLC/JHS	53	26.5
None	100	50
Total	200	100

Table 4.2 depicts the educational levels of respondents interviewed. Out of 200 respondents, 50% of the farmers have no formal education (None) whereas 50% did attend and reached various levels of the educational ladder such as MSLC (26.5), O'Level/SHS (14.5%), Post-Secondary (6.5%) and Tertiary (2.5%). Extremely low level of education has been reported to affect the level of technology adoption and skills acquisition among farmers (Oyekale and Idjesa, 2009).

The existence of two (2) Health institutions, four (4) Senior High Schools (all of which offer agricultural science) and fifty (50) Junior High Schools (both government and private) in the district could help reduce the illiteracy level. Notwithstanding, illiteracy is still a limitation to sustainable maize production under rainfed condition since it can affect farming practices and adoption of new technology. This confirms the perception that most farmers are not formally educated, may be unskilled with extremely low economic return as modern agriculture is more than tilling the soil (MoFA, 2012). Due to this, MoFA offers career opportunities in research, environment, financial management, engineering and other technical areas for the farmers especially the youth. To a large extent, illiteracy threatens other production dependants such as extension education, technology and innovation. According to Badal and Singh (2001), educational level of farmers affects extension services and access to credit facility which are important factor that have influence over farmers' ability to adopt improved technology in maize production. Basic education is important for smallholder maize farmers to enhance adopt new technologies and practices.

Table 4.3: Age and farming experience

Age group (Years)	**Farming experience (Years)**							
	1-5	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**> 30**	**Percent (%)**
< 20	10	-	-	-	-	-	-	5.0
21-30	1	17	-	-	-	-	-	9.0
31-40	-	8	38	1	-	-	-	23.5
41-50	-	-	-	52	29	-	-	40.5
51-60	-	-	-	-	5	24	1	15.0
> 60	-	-	-	-	-	-	14	7.0
Total (%)	5.5	12.5	19.0	26.5	17.0	12.0	7.5	100

Table 4.3 shows the age distribution and experience in maize farming in Tano North District. It can be seen that the 41-50 age group was 40.5%, 31-40 age group 23.5% and the least is those below 20 years which is 5%. Majority of farmers are above their youthful age (40 years group) and they cannot increase and sustain maize production in the study area under the current production methods. This agrees with the assertion made by Mauricio (2000) that the age of the farmer would have a positive effect on technical incompetence. Older farmers could be more traditional and conservative and show less willingness to adopt new practices.

This is a clear indication that the rainfed maize production is not attractive to the youth (below 40 years) in the study area. This confirms the findings of Abdulai and Huffman (2000) that the youth are not involved in farming because they want quick money and travel out of rural or farming towns and communities to seek non-farm jobs. With this in mind the future and for that matter maize sustainability in the study area may be difficult to realize or achieve.

The highest experience in maize farming is 16-20 years (26.5%), followed by 11-15 year (19%) with the least being 1-5 years (5.5%). This implies that the respondents have much experience in the farming enterprise. However, according to Osei *et al.* (2013) people with very low formal educational background who are old rarely try innovations. Having been in the business for long would give the farmers a false sense of satisfaction which could impact negatively on technology adoption.

Table 4.3 shows that 62.5% of respondents ranging from 41 years to above 60 years have been in maize production for 16 years and above. This supports MoFA (2012) view that farmers' population in the district is ageing which must be addressed to facilitate sustainability in agricultural production. Farm labour is one of the vital ingredients in maize production. The old age suggests that farmers do not have the necessary energy to work and manage. Thus, farmers resort to hired labour, mostly dominated by the youth, for crop production which is scarce and expensive.

Land Acquisition and Ownership

The research revealed that the farm lands are owned by families and individuals. Respondents who are land owners were 57 (28.5%) whereas 143 (71.5%) of them did not own land but acquired one through the land custodians.

Table 4.4: System of land acquisition

Systems	Frequency	Percent (%)
Abunu	0	0
Abusa	85	59.4
Hired	39	27.3
Others	19	13.3
Total	143	100

Out of 143 respondents, farmers who do not own land (Table 4.4) 59.4%, 27.3% and 13.3% acquire land through *abusa* agreement, hiring and others (like friends or rented house land lord/lady) respectively. *Abunu* land acquisition agreement for maize cropping does not exist unless for cocoa cultivation. Share tenancy is based on two principles of "*abunu*" and "*abusa*". It involves share cropping such as *abunu* which is a sharing on 50:50 basis between the land owner and tenant; and *abusa* which is sharing on a 1:2 between the landowner and tenant. This suggests that the land custodians need to be educated on the equal importance of the two crops in the study area.

Table 4.5: Difficulty in land acquisition for farmers who do not own land

Difficulty	Frequency	Percent (%)
Yes	134	93.7
No	9	6.3
Total	143	100

Currently land acquisition in the study area is very difficult due to the land owners' assertion that maize cropping encourages grass land, low fertility, and bush fires among others (Table 4.5). Comparing maize to cocoa, the latter fetches more in everything than the former, in terms of government support, land fertility, financial assistance among others cocoa is ahead in the district.

4.2 Current Rainfed Maize Production Practices

4.2.1 Land preparation, timing, indicators and cost

Timely, well prepared/cultivated land combined with quality seed, favourable planting time, good cultural practices and favourable weather/climatic conditions results in high yield. With this, it is important to know the indicators that determine the time of land preparation in the major and minor seasons so as to achieve high yields.

Indicators for land preparation in the major season

The study revealed that the indicators to determine the time of land preparation in the major season are shown in Table 4.6. From the table, “following colleague farmers” (50.5%) leads the indicators which is followed by “signs of onset of major rainy season” (25.5%), whilst the least is “following weather forecasts” (2.5%). These imply that the farmers do not follow the weather forecasting which is scientific and beneficial in the long term.

Table 4.6: Indicators of land preparation for the major season

Indicators	Percent (%)
Signs of onset of major rainy season	25.5
Coming of Easter	7.0
Availability of funds/others	5.5
February ending	6.0
Follow colleague farmers	50.5
Cannot tell	3.0
Follow weather forecast	2.5
Total	100

Timing of land preparation in the major season

Timely land preparation is crucial in maize production in the sense that the planting time of the crop should coincide with the rains else the rains may either stop when it is needed or continue when it is not needed. Therefore, when the land is timely prepared then planting can be carried out on time to meet favourable rainfall and other climatic conditions.

Table 4.7: Timing of land preparation in the major season

Land preparation time	Frequency	Percent (%)
1st week of Feb.	0	0.0
2nd week of Feb.	10	5.0
3rd week of Feb.	44	22.0
4th week of Feb.	41	20.5
1st week of March	35	17.5
2nd week of March	20	10.0
3rd week of March	17	8.5
4th week of March	5	2.5
1st week of April	2	1.0
2nd week of April	3	1.5
3rd week of April	21	10.5
4th week of April	2	1.0
Total	200	100.0

According to Cox *et al.* (2006) it is a general agricultural practice in Ghana for farmers to clear the forest or burn the grass during the dry season from December to February, and prepare the land for planting when the major season commences. From Table 4.7, 42.5% of the respondents get the major season land preparation done in 2nd half of February, followed by 27.5% in the 1st half March. This suggests that almost 70% of respondents prepare their land from Mid-Feb. to Mid-March for maize production.

Table 4.8: Methods of land preparation in the major season

Method	Percent (%)
Slash and burn	22.5
Tractor ploughing	0.0
Zero Tillage	5.0
Herbicide/Slash and burn	72.5
Total	100.0

Maize performs best in deep, well-drained, medium to coarse textured soils, but producers have successfully produced maize on a wide range of soil types. Perhaps the most important consideration for land selection is drainage (Cox *et al.,* 2006).

According to the survey conducted, the method of land preparation for the major season, are slash and burn (22.5%), zero tillage (5%) and herbicide application/slash and burn (72.5%). There was no tractor ploughing (Table 4.8). Slash and burn method can reduce the productive level of the soil since macro and micro soil organisms can be burnt during the burning process (Cox *et al.,* 2006). Also, the moisture content of the soil is reduced after the burning process which is worst when the rainfall is erratic.

The reasons for the choice of land preparation could be attributed to the land preparation method (Table 4.8) employed. The slash and burn/herbicide application method which the majority of the respondents employed needs sufficient sunshine for drying before burning and time for re-emergence of the weeds before herbicide is applied to pave way for sowing of seeds. This suggests that early land clearing can enhance good land preparation to catch up with the onset of rainy season.

Land Preparation Indicators for Minor Season

The survey revealed that 94 out of 200 respondents are involved in minor season maize farming. This suggests that minor season maize farming in the study area is not carried out by all maize farmers.

About half of the minor season maize farmers prepared their land after the major season harvest (51.1%) with only about 3% following weather forecast (Table 4.9). This suggests that respondents hardly receive or utilize information on weather forecast before the commencement of the minor season land preparation, hence, reliance on their traditional way of indicating time for land preparation.

Table 4.9: Indicators for land preparation in the minor season

Indicators	Frequency	Percent (%)
Signs of onset of minor rainfall	20	21.3
After major season harvest	48	51.1
Availability of funds/others	8	8.5
Reference from last year’s rains	15	16.0
Follow weather forecast	3	3.1
Total	94	100

Minor season farming starts, according to 94 minor season maize farmers, immediately after the harvesting of the major season produce. The same farming tools used in the major season are also applied in the minor season. There is no clear trend in terms of the month for which the minor season land preparation is done. The land preparation is done from the middle of June to late August (Table 4.10), but mostly in late July – early August.

Table 4.10: Time for land preparation in the minor season

Time of land preparation	Frequency	Percent (%)
1st week in June	0	0.0
2nd week in June	0	0.0
3rd week in June	3	3.2
4th week in June	10	10.6
1st week in July	0	0.0
2nd week in July	4	4.3
3rd week in July	8	8.5
4th week in July	22	23.4
1st week in August	30	31.9
2nd week in August	9	9.6
3rd week in August	5	5.3
4th week in August	3	3.2
Total	94	100.0

Estimated amount spent on land preparation

The estimated amount spent on land preparation per acre by the respondents varies from above GH¢500 to below GH¢99.00. Table 4.11 shows that farmers who spend below GH¢99.00 are the majority (37%), followed by GH¢ 100-199 (28.5%) and the least is above GH¢ 500 with 3.5%.

Table 4.11 Estimated amount spent on land preparation by the respondents

Amount in Ghana Cedis/acre	Percent (%)
> 500	3.5
400-499	4.5
300-399	8.5
200-299	18.0
100-199	28.5
< 99	37.0
Total	100

Meanwhile, according to MoFA, the cost of land preparation in the district is GH¢129 per acre as tabulated in the maize crop production budget for an acre of land (Table 4.12). Reconciling both the respondents and the MoFA estimates, it is clear that most of the farmers produce under a low financial resource. Thus farming may demand more than the farmers can afford when it comes to preparing the land for maize production. Again some farmers abandon their farms in the middle of the season due to financial problems.

Table 4.12: Estimates for land preparation

Item	Quantity/acre	Unit Price (GHc)	Amount (GHc)
Slashing (Person)	4	15	60
Burning (Person)	1	15	15
Herbicide (Litres)	3	9	27
Labour for herbicide application (Person)	1	15	15
Miscellaneous	-	-	12
Total	-	-	129

Source: MoFA (2012)

Farmers find it very difficult to cultivate large area of land and hence cultivate below 0.8 ha in the district (see Table 4.26).

4.2.2 Seed variety and source

Seed is a significant technological parameter required to increase agricultural yield. Seeds are the most precious resources of farmers and concern about viability of agricultural systems usually centres on the diversity and stability of the seed supply system (Tripp, 2001).

Seeds planted are mainly from the previously harvested grains, which accounts for 72.5% of the seeds used by respondents. The rest, of 20.5% and 7% obtained the seed from accredited agents and neighbours respectively are as shown in Figure 4.1.

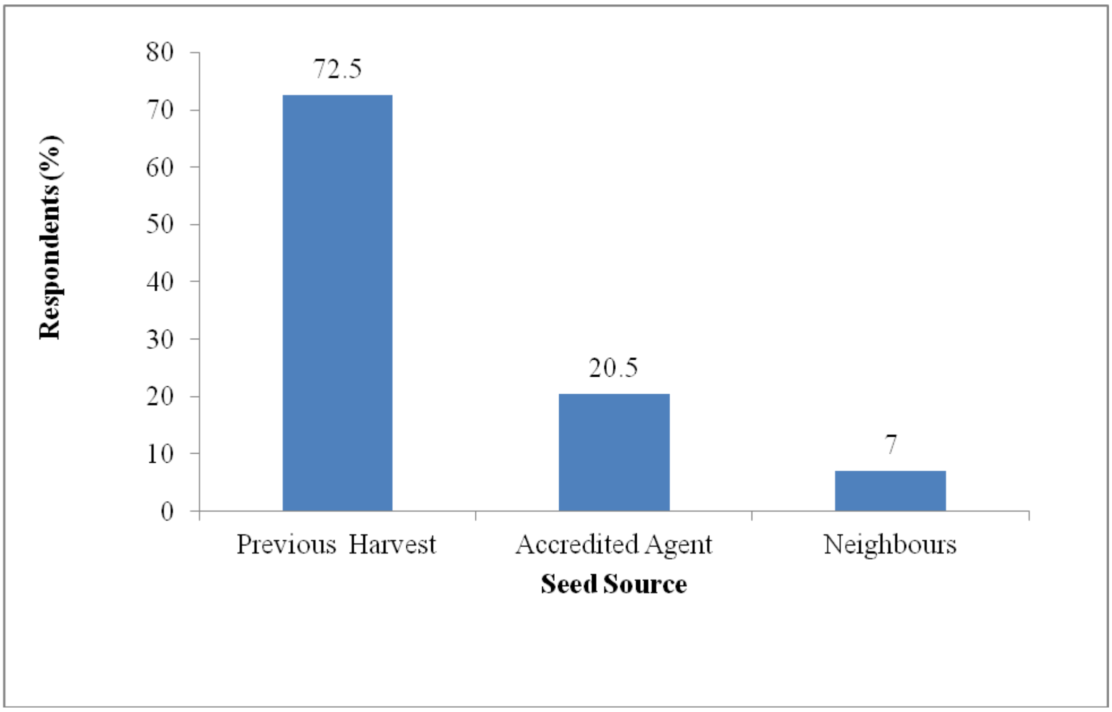

Figure 4.1: Sources of seed from respondents

Therefore, the use of uncertified seeds is high in the study area. Farmers need training in seed technology. E-TIC (2012) assertion that low yield in Sub-Saharan Africa may be attributed to poor seed selection may be applicable here. Farmers practice with regards to seed selection implies 'seed recycling' which can be a contributory factor to low yields. The yield level of recycled variety reduces due to loss of vigour when recycling persists. This is in line with the report by Wanyama *et al.* (2005) that yield levels of recycled maize variety-'H614' reduced by 15.86%, 16.70%, 32.25% and 46.80% for the first, second, third and fourth recycling generations respectively and noted a progressive loss in grain yield when maize is recycled by farmers.

Seed variety

The *Obaatanpa* variety is predominantly grown as it accounts for 59% of the variety planted by respondents. It is followed by *Okomasa* (long cob) with 37% also an improved variety because of its long and thin cob. The last variety is the local maize as it also accounts for 3.5%. The varieties chosen are based on numerous reasons. These include high yield/quality of grains, market demand, early maturity and drought resistance as shown in Table 4.13. With the local maize, the respondents indicated that apart from the tabulated qualities, it does not attract weevils' infestation due to its low nutritional content, good dough texture and less chaff.

Table 4.13: Criteria for seed selection

Reasons	Obaatanpa	Okomasa	Local maize	Total	Percent
More/Quality grains	30	36	2	68	34
Market requirement	46	19	0	65	32.5
Early maturity	42	20	0	62	31
Drought Resistance	0	0	5	5	2.5
Total	118	75	7	200	-
Percentage (%)	59	37.5	3.5	-	100

Meanwhile, the survey revealed that 193 farmers planted *Obaatanpa* and *Okomasa* varieties in every season during the major and minor seasons. According to the CRI (2005), these two varieties are medium and late maize varieties, having maturity days of 105 and 120 respectively. Again, the potential for *Obaatanpa* and *Okomasa* are 4.45 t/ha (44.53 maxbags/ha) and 4.86 t/ha (48.58 maxbags/ha) respectively. The survey showed clearly that majority of the farmers interviewed were not able to achieve the CRI potential. However some of the famers in the district perceived their yields as high.

Number of seeds sown

According to the survey conducted in the study area, the number of seeds planted per hill in both major and minor seasons is as presented in Table 4.14. Thus, 4 seeds (42.5%) 3 seeds (39.5%) and 2 seeds (18%) have been the planting practice in the major season per hill. It can be figured out that 82% of the respondents plant more than 2 seeds (that is 3-4 seeds) per hill. The two seeds per hill planting practices may not be helpful on account that, not all seeds germinate, requiring refilling that brings added cost. It is also about the viability of seeds, waste of seeds and cost. However, according to Hashemi *et al.* (2005), maize is among the least tolerant of crops to high plant population densities.

Table 4.14: Seeds planted per hill

	Major season		**Minor season**	
Seeds per hill	**Frequency**	**Percent (%)**	**Frequency**	**Percent (%)**
2	36	18	39	41.5
3	79	39.5	50	53.2
4	85	42.5	5	5.3
Total	200	100	94	100

Seed Germination

Figure 4.2 shows that majority of the respondents have almost all their seeds germinated (91%), 7% had few seeds germinated and 2% have all seed germinated.

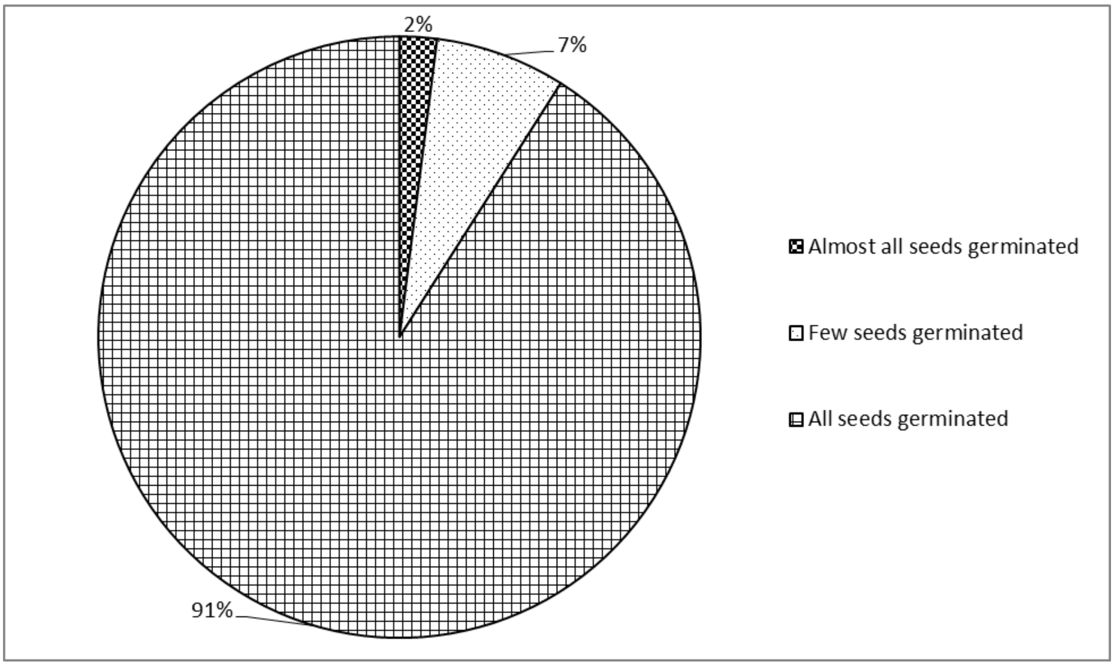

Figure 4.2: Seed germination

Farmers attribute poor germination to unfavourable climate conditions, birds/rodents' destruction and time of planting (Table 4.15). It must be noted that farmers do not perform germination test to ascertain the potency of the seeds before sowing.

Table 4.15: Reasons for germination pattern changing in all seasons

Reason	**Percent (%)**
Unfavourable climatic conditions	60.5
Birds/Rodents destruction	17.0
Time of planting	22.5
Total	100

Seed treatment

The survey revealed that 66% of the respondents did not use any seed protection chemical on the seeds before sowing. But 34% of the respondents applied chemicals such as Dichloro Diphenyl Trichloroethane (D.D.T) which is a banned product as seed dressing before sowing. This chemical is applied purposely for protection against termites and birds, especially for late sowing and too early before the beginning of the major season (Table 4.16).

Table 4.16: Chemical protection of seeds before sowing

Response	Percentage
Yes	34
No	66
Total	100

The survey revealed that, 61.8% (Table 4.17) of those who applied chemicals to the seeds before sowing left the used containers on the farm. Meanwhile, the used containers are made of plastic that are not biodegradable hence become dangerous to the environment and can also lead to human poisoning. The 38.2% of respondents either buried used containers or left the containers in the house for reuse.

Table 4.17: Disposal of agro-chemical containers

Place	Percent (%)
Left on the farm	61.8
Buried	10.3
Left in the house for reuse	27.9
Total	100

4.2.3 Cropping system and planting pattern

There are two systems of cropping practiced in the study area. Namely mono-cropping and mixed cropping but the latter is more preferred by the farmers (Table 4.18).

Table 4.18: Cropping system

Cropping system	Percent (%)
Mono cropping	20.5
Mixed cropping	79.5
Total	100

The reasons for mixed cropping according to the respondents include: saving in labour cost, land security, gives variety of food stuffs and finally provides an alternative when the main crop (maize) fails. Notwithstanding the reasons given by the 79.5% of the respondents, 20.5% of the respondents also practice monocropping and the following reasons were given: easier pests and diseases control, maximum use of soil nutrients, and easy weed control and other cultural practices.

Certainly, the farmers being subsistence, think and hope that they will obtain enough to feed their families and if possible sell the surplus. Obviously, the respondents' values differ from the experts' values.

Out of 159 mixed cropping respondents (Table 4.19), about 17% intercropped with leguminous crops like beans (cowpea and climbing beans) and groundnut. The remaining 83% mixed with cocoyam, plantain, cassava and vegetables. The pattern of the maize and the purpose of the leguminous crop planted are either for food or for money or as a source of soil fertility.

Table 4.19: Mixing leguminous crops with maize

Response	Percent (%)
Yes	17
No	83
Total	100

Competition among mixtures is thought to be the major aspect affecting yield as compared with solitary cropping of cereals. Along with profitability for farmers, sustainability of agriculture and soil conservation may be improved in mixed cropping environments (Dhima *et al.,* 2007).

Table 4.20: Intercropping week after maize planting

Week	Frequency	Percent (%)
1st Week	5	18.5
2nd Week	19	70.4
3rd Week	3	11.1
Total	27	100

The relative time of sowing a component crop is an important management variable manipulated in cereal - legume intercropping systems. Addo-Quaye *et al*. (2011) pointed out that differential sowing improves productivity and minimizes competition of growth-limiting factors in intercropping. Anil *et al*. (1998) also pointed out that sowing component crops at different times ensures full utilization of growth factors because crops occupy the land throughout the growing season.

From Table 4.20, 27 respondents in general intercropped leguminous crops with the maize. About 70.4% of the farmers sow leguminous crops 2nd week after maize planting, 18.5% and 11.1% of the respondents sow it 1st and 3rd week respectively. A study by Addo-Quaye *et al*. (2011) on maize intercropped with four contrasting cowpea cultivars sown 5 - 10 days apart, suggests that near-simultaneous sowing of component crops is optimal to attain the highest combined yields and intercropping efficiency. Anil *et al*. (1998) confirmed that manipulating the time intervals between growth durations of component crops influences efficiency of cereal - legume intercrop systems.

Planting method

The research revealed that 82% of the respondents sow randomly and 18% also practice the recommended row planting. Ghodratollah and Masoud (2009) revealed that row planting pattern had significant effect on grains light interception, leaf area index and grain yield.

Cox *et al.* (2006) argued that uneven plant spacing and emergence may reduce maize yield potential. Seed should be spaced as uniformly as possible within the row to ensure maximum yield, regardless of plant population and planting date.

Table 4.21 Planting method

Planting method	**Percentage (%)**
Row	18
Random	82
Total	100

Respondent farmers who practice random sowing asserted that it saves time and it is less labourious, less expensive, higher seed rate and encourages mixed farming. CRI (2005) confirmed that random sowing is the commonest method of sowing since it is the easiest, quickest, time saving, requires minimum labour and higher seed rate but resource utilization is non-uniform (either under utilized or over exploited) and mechanization is not possible due to no equal space.

Table 4.22 indicates various reasons given by farmers why they plant in rows. Majority of farmers who plant in row (52.8%) indicated that row planting increase yield; others do so because extension officers advised them (33.3%) and also row planting eases field management (13.9%). The fact that majority of farmers perceive that row planting increases yield is good in order to increase production per cropping season. This is because row planting enhances plant population density per unit area, thereby increasing yield. In effect farmers can get more income and save some capital for cropping or farming in subsequent season, thereby sustaining production.

Table 4.22 Reasons for row planting

Reasons	**Frequency**	**Percent (%)**
Ease of field management	5	13.9
Increase in yield	19	52.8
Advised by extension officer	12	33.3
Total	36	100

The reasons given agree with the work of Ghodratollah and Masoud (2009) who indicated that the highest biological yield was produced in the highest plant density, while the least plant density produced the lowest grain yield.

Planting tools

Maize is usually planted manually using hand hoes, cutlasses or dibblers depending on local tradition (Adjei *et al*., 2003; Tweneboah, 2000) resulting in high labour requirements and drudgery.

Table 4.23: Planting tools

Planting tools	Percent (%)
Line and stick	6
Line and cutlass	12
Dibbler	82
Seed planter	0
Jab planter	0
Total	100

From Table 4.23, the most important planting tool used by the respondents is the dibbler (82%), followed by the line and cutlass 12%, and line and stick 6%. This suggests that farmers still use traditional methods for planting which they need to improve for sustainable maize production in the district. The respondents indicated that they have no idea about seed planters as well as the Jab Planter.

Table 4.24: Reasons for changing planting time

Reason	Percent (%)
Changing rainfall pattern	94.5
No money	5.5
Total	100

Almost 95% of the respondents attributed changing planting time and month to changing rainfall pattern whereas 5.5% mentioned “no money” as a reason for changing planting month.

Planting period and pattern

The period of planting is very crucial in the sense that the nature of the variability of weather/climate is such that if the critical period of the plant growth coincides with favourable climatic conditions then, the plant will do well and result in high yield. It is therefore important to choose a favourable planting time to meet the required amount of rains for crop growth and productivity.

Timely and early planting is one of the most basic requirements for good crop production (Cox *et al.*, 2006). Early planting benefits from the higher soil fertility present at the beginning of the rainy season. As the season progresses, nutrients leach below the root zone and are therefore no longer available for uptake. Early planting also benefit from more days of sunshine.

Too early planting means leading the onset of the rainfall, birds compete with seed germination by means of eating the sown seeds that are not germinated because of lack of moisture.

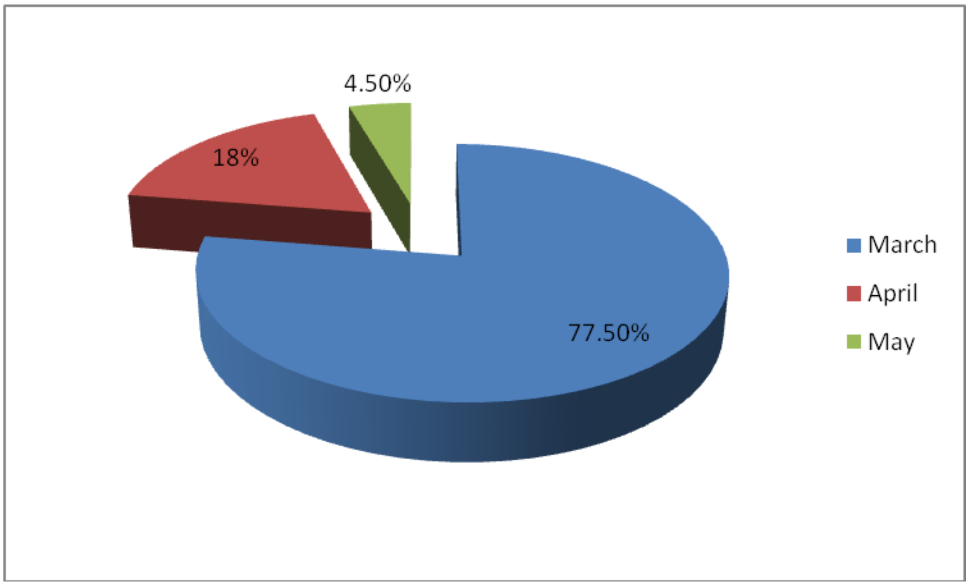

Figure 4.3: Planting period and pattern

Planting in the major season spans March to May, however, 77.5%, 18% and 4.5% of the respondents sow their seeds in March, April and May respectively (Figure 4.3). The minor season sowing is done from July through to September.

Respondents' observation of varietal growth characteristics

The growth stages go with days/period so when the period is due for the physiological development to emerge or correspond and it does not occur then there is a problem somewhere which can be caused by among other things soil nutrient deficiency, climatic variations, and seed variety. The days to tasselling, silking, and maturity stages are as presented by the farmers.

Table 4.25: Tasselling, silking and maturity days for Obaatanpa, Okomasa and Local

Growth stage	Days	Variety (%)		
		Obaatanpa	**Okomasa**	**Local**
Tasselling	55-60	101 (85.6%)	66 (88.0%)	0
	61-65	17 (14.4)	9 (12.0%)	0
	66-70	0	0	7
Silking	60-65	25 (21.2%)	11 (14.7%)	0
	66-70	93 (78.8%)	64 (85.3%)	0
	71-75	0	0	7
Maturity	90	110 (93.2%)	71 (94.7%)	0
	105	8 (6.8%)	4 (5.3%)	2 (28.6%)
	120	0	O	5 (71.4%)

Out of 118 *Obaatanpa* variety farmers, 85.6% and the remaining 14.4% of them had their maize tassel at days between 55-60 and 61-65 respectively. Of the respondents who sow *Okomasa* maize variety, 88% and 12% said their maize tassel 55-60 and 61-65 days respectively. All the 7 respondents who sow local maize have it tasselling at 66-70 days. This confirms CRI (2005) findings that the last branch of the tassel is completely visible at day 55 for all normal maize plant and will augur well for the sustainability of maize production.

Table 4.25 shows that 78.8% and 21.2% of respondents said their maize silk at 66-70 and 60-65 days respectively (*Obaatanpa*). Out of the respondents that sow *Okomasa* maize variety 85.3% and 14.7% said their maize silk 66-70 and 60-65 silking days respectively. All the local maize respondents said their maize silk 71-75 days. The respondents had a conflicting silking days compared with CRI (2005). This suggests that environmental stress like fertility and soil moisture may influence the lengthening of the growth stage which should be looked at to sustain production.

According to the survey, 93.2% and 6.8% of the *Obaatanpa* maize respondents mature 90 days and 105 days respectively. Out of the respondents that sow *Okomasa* maize variety, 94.7% and 5.3% said their maize matures in 90 days and 105 days respectively. Furthermore, 28.6% and 71.4% of the respondents who grow the local maize said it matures in 105 days and 120 days (four months) respectively (Table 4.25).

On the contrary, according to the Crops Research Institute (CRI), Kumasi, *Obaatanpa* and *Okomasa* are medium and late maize varieties having maturity days of 105 and 120 respectively, and with days to silking of 55 days. This suggests that farmers in the study area are getting the growth characteristics wrong by not being very observant.

4.2.4 Farm size, yield and perception of level of production

The survey revealed that 50.5% (101 respondents) cultivated on less than 0.8 ha land and out of this 80 respondents (40%) achieved < 0.63 t ha^{-1} yield and 21 respondents (10.5%) obtained a yield of 0.63-1.25 t ha^{-1}. Also 62 respondents (31%) and 8 respondents (4%) cultivated maize ranging between 0.8-1.6 ha and 1.6-2.4 ha respectively with yields between 0.63-1.25 t ha^{-1}. Farmers who cultivated on large farm size had higher productivity. The farm size of 2.4-3.2, 3.2-4.0, and 4.0-4.8 hectares had yields of 1.25-1.88 t ha^{-1}. Though in the minority, farmers with 4.8-8.0 ha or above farms obtained yields of above 1.88 t ha^{-1}(Tables 4.26).

The acreage a farmer cultivates determines the resourcefulness of the farmer. The size of the farm is land and other resources availability dependent which differs from season to season. This agrees with the report made by Ghosh (2004) that the farm size cultivated has positive effect on the net income or yield.

Table 4.26: Farm size and crop yield of the respondents

Farm size			Yield		
Farm (ha)	**Frequency**	**Percent**	**Yield (t/ha)**	**Frequency**	**Percent**
< 0.8	101	50.5	0.50-1.25	101	50.5
0.8-2.4	70	35	0.50-1.25	70	35.0
2.4-4.8	17	8.5	1.25-1.88	17	8.5
4.8-8.0	11	5.5	> 1.88	11	5.5
> 8.0	1	0.5	> 1.88	1	0.5
Total	200	100	Total	200	100

About 78% of the respondents very often keep to their normal farm size season after season due to constraints beyond their control. Among the constraints highlighted was lack of logistics or input support. This suggests that maize farmers in the study area do not change their farm size season after season and this can hamper sustainability of maize production. But the remaining 22% of the farmers either reduce or expand their farm sizes depending upon the availability of resources.

Respondents' perception of level of production

Table 4.27 indicates that the yield obtained by the maize farmers is qualitatively perceived as average (47.5%), low (40.0%) and high (12.5%). Therefore, the farmers accepted the fact that they are under producing but they quickly added that, it would continue if MoFA, government and financial institutions keep running away from them, by not providing credit facilities and other resources needed to really sustain and increase yield.

Table 4.27: Perception of the yield obtained by the farmers

Yield obtained	Frequency	Percent (%)
High	25	12.5
Average	95	47.5

Low	80	40.0
Total	200	100

Table 4.28: Reasons for low yield

Reasons	Frequency	Percent (%)
Rainfall pattern (onset, erratic, amount)	127	63.5
Lack of suitable crop variety	3	1.5
Pests and disease attack	51	25.5
Weeds infestation	12	6.0
Infertility/Germination failure	7	3.5
Total	200	100

Table 4.28 shows that most of the farmers (63.5%) attributed the low yield of maize crop to rainfall pattern, followed by pests/diseases attack (25.5%). This was confirmed by Ofori and Kyei-Baffour (2006) that climate is one of the most important limiting factors for maize production in the tropics particularly rainfall. It has again been argued that crop infection and infestation by diseases, insects and weeds can significantly reduce yield in both temperate and tropical regions.

Farmer's knowledge on yield potential of maize crop

Yield potential refers to the highest yield achievable on farmers' fields, with the use of improved seed (high yield, tolerance to diseases and pests) appropriate level of nutrients, water and weed control (CRI, 2005). Table 4.29 depicts that respondent farmers have no knowledge on yield potentials of the crop varieties planted. This suggests that farmers are not receiving the requisite extension education. The farmers claimed that attention by developmental agencies, government/MoFA is on cocoa farmers in the district.

Table 4.29: Farmers knowledge on yield potential

Farmer Knowledge	Percent (%)
Yes	0.0
No	100
Total	100

4.2.5 Financing, inputs and extension support

Sadly, due to the farmers' inability to access funds on their own due to circumstances beyond their control such as collateral securities, enter into what it is locally called "*Bekuuba*" support from maize retailers and friends. This is simply extortion from the farmers because of the repayment terms. A farmer receives a financial assistance that is worth equivalent to a bag of maize at the beginning of the growing season and then the farmer is obliged to settle with two bags or its cash equivalent and if possible sell all the maize (grains) to them after harvesting or storage. This suggests that farmers pay high interest and are not financially motivated to access financial credits due to repayment terms which do not help the farmers to breakeven after their hardwork.

Table 4.30: Sources of financial assistance to farmers

Agency	Frequency	Percent (%)
Government	0	0.0
Bank	15	7.5
Friend	61	30.5
Others (Retailers)	85	42.5

As stated by Obeng-Ofori (2008), high interest rates have detrimental effect on farming in Ghana since growth and development of the sector depends upon adequate available and accessible funds at favourable rates.

Input support

Table 4.31 indicates that 70.5% of the respondents do not receive input support. Among the 29.5% (59) that receive input support found it inadequate for high and sustainable production 42.4%, 40.7% and 16.9% receive herbicides, seeds and fertilizers (NPK) respectively (Table 4.32) from maize retailers, friends and MoFA. It was realised that MoFA supplied 10 bags of fertilizers to 10 farmers to be applied on the experimental field. The outcome of the survey indicates that farmers have a serious challenge in obtaining credit or inputs for their farm activities.

Table 4.31: Input support for farmers

Input	**Percent (%)**
Yes	29.5
No	70.5
Total	100.0

Table 4.32: Kind of inputs for farmers

Kind of inputs	**Frequency**	**Percent (%)**
Seeds	24	40.7
Fertilizer	10	16.9
Herbicide	25	42.4
Total	59	100.0

Accessibility of agricultural extension services

The importance of agricultural extension in rural development is widely acknowledged, particularly in developing countries where the majority of the population lives. Agriculture is the main source of livelihood, and access to information is important for agricultural sustainability (Wanga, 1999).

Extension service is critical to the sustainability of maize production. Farmers' access to extension services is discouraging in the study area. This is depicted in Table 4.33 where only 5.5% of the total respondents responded to have good (2.5%) and average (3%), with the majority (94.5%) of the farmers indicating that they had poor access to extension. The majority indicated that they are unattended to because they are of less value compared to cocoa farmers in the district. Based on this, it can be said that farmer's extension accessibility has led to yield decline in the study area and the end result will be unsustainable rainfed maize production.

Table 4.33: Extension services accessibility

Accessibility	Percent (%)
Very good	0.0
Good	2.5
Average	3.0
Poor	94.5
Total	100.0

Educational training for the farmers

Table 4.34 shows that only 5% of respondents had "average" access to educational training. This suggests that farmers in the study area cannot access agricultural education training which may be a factor in the low yield.

Table 4.34: Access to educational training for the farmers

Assessment	Percent (%)
Very good	0
Good	0
Average	5
Poor	95
Total	100

Extension support services from MoFA

The survey revealed that maize farmers do not receive land preparation and climatic conditions education from MoFA in the study district but 5.5%, 6%, 5.5%, 5% and 5% of respondents receive planting technique, fertilizer application, harvesting, storage and seed supply services respectively from MoFA (Table 4.35). This suggests that farmers are handicapped as dissemination of information relating to advanced technology in sustainable agricultural production, which include supply and usage of improved seeds, land preparation, planting technique, fertilizer and other chemical application among others as one of the objectives of agricultural extension in Ghana (Bokor, 2005) is not available to the farmers in the district.

Table 4.35: Services rendered to the farmers

Services	Frequency	Percent (%)
Land preparation	0	0.0
Planting technique	11	5.5
Fertilizer application	12	6.0
Harvesting	11	5.5
Storage	10	5.0
Seed supply	10	5.0
Climatic condition	0	0.0

4.3 Environmental Sustainability Practices

4.3.1 Soil fertility management

In terms of fertilizer application, only 6% of respondents (Table 4.36) use this practice which is done mainly by surface placement. Ideally, fertilizers should be applied twice to maize crop in a season, specifically first, NPK and second Ammonia application 2 and 4-6 weeks respectively after planting as recommended by research outputs. However, 94% do not apply fertilizer.

Table 4.36: Fertilizer application

Application	Frequency	Percent (%)
Yes	12	6
No	188	94
Total	200	100

Table 4.37 reveals the lack of funds (high cost of the fertilizer and its application) 86.5%, land has sufficient fertility (8.5%) and or both (5.9%) are the reasons for non-application of fertilizers to respondents maize farms. It confirms that low yields of maize can be attributed to traditional farming practices such as the use of low-yielding varieties, poor soil fertility and limited use of fertilizers, low plant population, and inappropriate weed control and erratic rainfall (Heisey and Norton, 2007). Report of FAO (2002) equally confirms that maize yield increase with optimum use of fertilizer in Ghana. This suggests that sustaining maize production in the study area, requires education and making fertilizer available to farmers.

Table 4.37: Reasons for non-application of fertilizer

Reason	Frequency	Percent (%)
Lack of funds	161	85.6
Land has sufficient fertility	16	8.5
No money/land has sufficient fertility	11	5.9
Total	188	100.0

4.3.2 Bush fires management

The study area experiences bush fires every year, caused by smokers, hunters (*kyeno kyeno* (catch it-catch it)), Fulani herdsmen and early season farming. Table 4.38 shows that smokers are considered the most causal agents of bush fires 42.8%, followed by hunters popularly known as "*kyeno kyeno*", 36.2%, early season farmers (17.4%) and Fulani herdsmen being the least with 3.6%.

Table 4.38: Causes of bush fires

Causes	Frequency	Percent (%)
Cigarette Smokers	59	42.8
Hunters (*kyeno kyeno*)	50	36.2
Fulani Herdsmen	5	3.6
Early season farmers	24	17.4
Total	138	100.0

4.3.3 Crop losses, transportation and storage

Grains may be lost in the pre-harvest, during harvest and post-harvest stages. Harvest losses occur between the beginning and completion of harvest, and are primarily caused by losses due to shattering (Azu, 2002). During stripping of maize grain from the cob, known as shelling, losses can occur when mechanical shelling is not followed up by hand-stripping of the grains that are missed. Certain shellers can damage the grain, making insect penetration easier (Magan and Aldred, 2007).

Table 4.39: Causes of Pre-harvest losses

Cause	Frequency	Percent (%)
Birds/Rodents	105	52.5
Pests/Diseases	50	25.0
Lodging	15	7.5
Theft	30	15.0
Total	200	100

Pre-harvest losses are predominantely caused by birds/rodents (52.5%), pests/diseases (such as termite attack) (25%), theft (15%) and lodging (7.5%) and as presented on Table 4.39. According to Shepherd (2012), pre-harvest losses occur before the process of harvesting begins, and may be due to insects, weeds, lodging and rusts. Magan and Aldred (2007) noted that maize is traditionally left to dry on the fields prior to harvesting through stoking for about 2-4 weeks. During stoking some losses are incurred through rodents, mainly rats and squirrels. The use of biological control with microorganisms, including fungi and bacteria, against plant pests and diseases has been found to be effective for reducing pre-harvest losses (Bayman, 2007).

Table 4.40: Causes of Post-Harvest Losses

Cause	Frequency	Percent (%)
Insects infestation (Weevils)	130	65.0
Transportation problem	43	21.5
Theft	11	5.5
Others (Rainfall)	16	8.0
Total	200	100

Table 4.40 shows that farmers perceive the causes of post-harvest losses as mainly due to insect infestation (weevils) (65%). Other causes are transportation (21.5%), rainfall (8%) and theft (5.5%). Important in many developing countries, particularly in Africa, are on-farm and storage losses when the grain is stored for auto-consumption or while the farmer awaits a selling opportunity or a rise in prices. Shepherd (1993) confirmed that in drying, grain that is dried in yards or on roads, as is common in parts of Asia and Africa (FAO, 2008), may be partially consumed by birds and rodents. Additionally, wind, either natural or from passing vehicles in the case of road drying, can blow grain away (Shepherd, 1993).

The adoption of the small scale metal silo in grain storage instead of the wooden crib can be a great step in reducing post-harvest losses of grains in the sub-Saharan region. However, FAO (2011), mentioned that the lowest losses were experienced in grains kept in houses and this could be attributed to close monitoring. Therefore, efficient post-harvest handling, storage and marketing can contribute to socio-economic development of rural communities and enhancement of sustainable maize production (Azu, 2002).

Transportation method

From Table 4.41 the most reliable and patronized transport system in the district is road transport using *Kia Truck* according to 52% of the respondents, followed by family head porting (26.5%), motorbike (15.5%) and bicycle (6%). It was noted that the quantity of maize harvested**,** the end use of the maize to the farmer and the distance of the farm that determines the transportation method.

Table 4.41: Means of transporting maize employed in the district

Means of Transport	Percent (%)
Family head porting	26.5
Kia truck	52.0
Bicycle	6.0
Others (motor king)	15.5
Total	100.0

Maize storage

The availability and safety of maize crop is threatened by insect pests, rodents and fungal attacks due to inappropriate storage facilities and methods. Infestation by insect pests accounts for between 20 to 50% of post-harvest losses in maize (Anankware *et al.*, 2012). From Table 4.43, 79.5% of the respondents store their produce in maize barns, 11% hang the maize on horizontal bars at the kitchen, where smoke is used as treatment agent, 5.5% of the respondents remove the husks and store the maize in cribs then treat with powdered actellic and expose to sunlight. Four percent of the respondents shell and treat the maize grains with liquid actellic and sunlight after which the treated grains are kept in sacks with some having inner white polythene.

Table 4.42: Maize storage facilities in the district

Facility	Frequency	Percent (%)
Maize barn	159	79.5
Cribs	11	5.5
Sack	8	4.0
Others	22	11.0
Total	200	100.0

Weevils have been singled out as the major causes of post-harvest grain losses. These losses are mainly due to the use of traditional storage structures that are inefficient in the storage and preservation of grain (Hell *et al*., 2000). In the Sub-Saharan region, it has been established that traditional cribs and sack bags which are the most common storage facilities, cannot guarantee protection against weevils and especially the larger grain borer that cause over 30 % of losses and sometimes wiping out the entire harvests during severe infestations (Schaafsma *et al*., 2001).

Grain weevils such as the larger grain borer, hibernates in the bamboo, the reeds and the tree branches of which our traditional structures are made. So it is quite a big problem because once it is there it is very difficult to control (Josphert *et al.*, 2012). But the metal silo method of grain storage starves them to death.

Treatment of maize before storage

The survey revealed that (Table 4.44) 53% of the respondents treat their maize before storage with chemicals like Actellic and DDT (Dichloro Diphenyl Trichloroethane); biological means use of *Chromolaena odorata* (‘*akyeampong*) leaves; and others like smoke/sunlight and wood ash. 47% of the farmers do not treat the maize before storage and intimated that there is no money for such processes.

The research established in Tables 4.43 and 4.44 that 72.6% employ chemical treatment method of which 76.6% use DDT and 23.4% use both powdered and liquid actellic. According to Anankware *et al.* (2012), pesticides and other artificial gaseous techniques for storing maize are no longer acceptable due to food quality and environmental related issues. This suggests that for most of the maize farmers are not abreast with current food safety requirement for treating maize before or after storage.

Research have shown that *Chromolaena odorata,* locally called '*akyeampong*', is the biological agent used to store maize in the barn for 3 - 4 months. This is by means of arranging the maize in husks on the plant leaves in layers, after that the maize is covered again with *Chromolaena odorata* leaves and this calls for further research.

Table 4.43: Treatment methods for maize storage

Method	Frequency	Percent (%)
Chemical	77	72.6
Biological ('*Akyeampong'* leaves)	11	10.4
Traditional/wood ash	18	17.0
Total	106	100

Additionally, 17% of the respondents use wood ash in treating maize in the storage barn. According to the respondents, the ash is spread in the barn where the maize is arranged in layers on the ash and for every layer of maize ash is sprinkled on it. This ash contains abrasive substance so weevils especially are afraid to go near else they (weevils) would be killed. The sprinkling should be timely to prevent the insect pests and rodents like mice from entry.

Table 4.44: Types of chemicals used in maize storage

Chemical	Frequency	Percent (%)
Actelic	18	23.4
DDT (Dichloro Diphenyl Trichloroethane)	59	76.6
Total	77	100

4.3.4 Crop residue management

Maize crop residues are the by-products generated from the maize plant apart from the maize grains. These are maize stalk, cob, husks, tassel and silk. From the respondents these are managed to benefit them.

Stalk and tassel management

The survey revealed that some of the farmers prepare herbal medicine with dry maize tassels and silks for cure of stomach ache and waist pains. Again, from the respondents, dry maize cobs are used as fuel source and toilet cleaning object in their homes. This signifies that there are more benefits in maize plant than just the grain to man.

Table 4.45: Maize stalk management practice

Practice	Percent (%)
Left on the field	70
Send home	17
Others (Burnt)	13
Total	100

From Table 4.45, 70% of the respondents leave the stalks on the farm after harvest, 17% send them home to feed their livestock or for herbal medicinal purpose and 13% are burnt on the field.

Table 4.46 shows that 43.5% of farmers responded that they have no use for the stalk. Whilst the majority of the respondents 56.5% said they derive benefits as listed in the table.

Table 4.46: Maize stalks benefit to farmers in Tano North District

Stalks benefit	Frequency	Percent (%)
Feed for livestock	13	6.5
Manure for the soil	43	21.5
Used as herbal medicine	5	2.5
As firewood	16	8.0
Others (Trapping/burnt)	36	18.0
Not needed	87	43.5
Total	200	100.0

Husks management

Out of 200 respondents, 90.5% do not remove the maize husk before transporting as shown in Table 4.48. The remaining 9.5% remove the husks and leave them on the field. Steve *et al.* (2012) explained that the husks left as residue on the field reflects sunlight and insulates the soil, reducing both warming and drying of fields. Excess maize husks increase the risk of pest infestations, including insects, diseases and rodents, and may intercept and tie up herbicides and nitrogen (N) (Steve *et al.*, 2012). The husks are managed when they are sent to the house either before or after storage to benefit the farmers either by selling or use for *kenkey* making.

Table 4.47: Maize husk management

Husk Removal	Percent (%)
Yes	9.5
No	90.5
Total	100

The research revealed that 47% of the respondents who do not remove husks and send them to storage points just burn the husks as unwanted product around their houses and sometimes close to the storage facility. About 42% of the respondents say they sell to traders and *kenkey* makers coming from outside or within the district. The 11% of the respondents themselves use the husks to prepare kenkey (Table 4.48). This suggests that maize husks are very important to some farmers.

Table 4.48: Response on Husks Management

Management	**Frequency**	**Percent (%)**
Burnt	85	47.0
Make kenkey	20	11.0
Sell to traders/kenkey makers	76	42.0
Total	181	100

Table 4.49: Maize crop production budget for an acre of land

Item	**Quantity/acre**	**Unit cost GH¢**	**Cost (GH¢)**
Land preparation	Acre	129	129
Seed (kg / 9 sachets)	9	4	36
Planting labour (people)	4	10	40
Fertilizer (NPK 15-15-15) (bag)	2	55	110
Labour for NPK application (people)	2	10	20
Weeding (people)	4	10	40
Sulphate of ammonia (bag)	1	50	50
Labour for SOA application (people)	2	10	20
Harvesting/gathering (people)	5	10	50
Transportation (kia)	1	40	40
Shelling/Dehusking (people)	4	10	40
Bagging (people)	4	10	40
Miscellaneous	-	-	31
Total	-	-	646

Source: MoFA (2012)

4.3.5 Farmers perception of herbicide effect on the environment

The survey revealed that as high as 72.5% of the farmers applied chemical herbicide such as sunphosate (Isopropylamine salt of glyphosate), *Adwuma wura* (Glyphosate 75.7g/kg), Destroyer (Dimethylamine salt of dicamba), glagold (Imazapyr and glyphosate), roundup (Glyphosate) among others in their land preparation. However, whether they have any knowledge on the effect of the herbicide on the environment is not clear. Figure 4.4 shows, 60% of the farmers interviewed responded affirmatively to lack of knowledge on the effect of herbicide on the environment, 22.1% believed herbicide destroys micro and macro organisms and 17.9% said that it increases fertility of the soil.

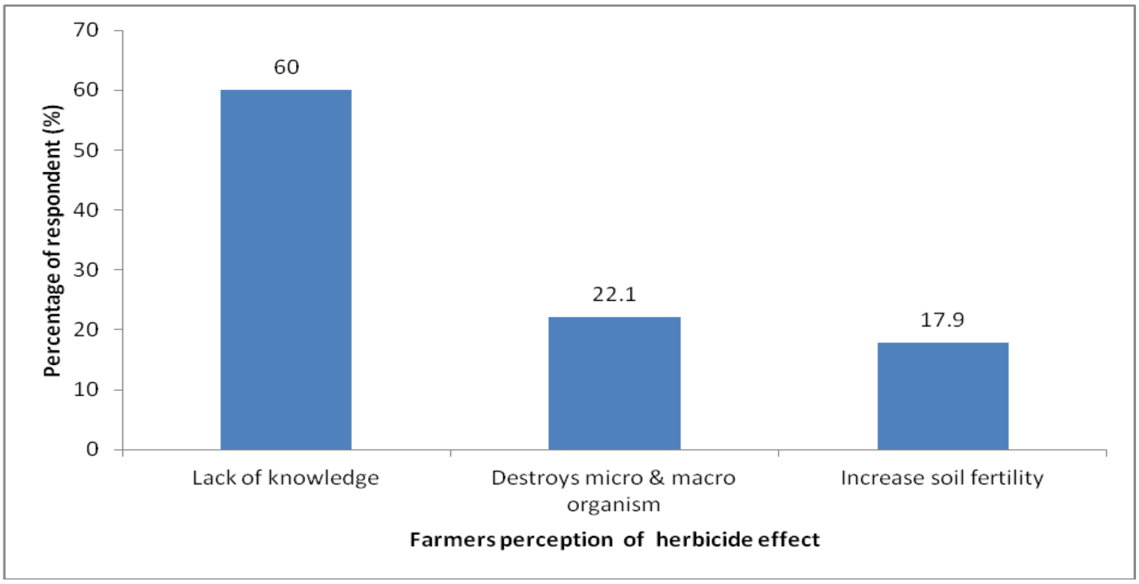

Figure 4.4 Knowledge of herbicide effect on the environment in Tano North District

The results suggest that most farmers do not consider the environment in their farming activities especially with regard to the use of herbicides. This is a threat to sustainable production of maize in the area, in that farmers are not conscious of the environment, and are unsure whether farming activities can endanger soil fertility and productivity as well. In a situation where the soil becomes unproductive, maize production will not be sustained. It can also be suggested that there is insufficient extension education to the maize farmers in the study area.

4.4 Rainfall Pattern and Characteristics

Climate, particularly rainfall, is the most important limiting factor for maize production in the study area, since rainfed agriculture is practiced. Generally, there was seasonal rainfall variability in the study area based on 20 – year rainfall records in the nearest station at Sunyani (Figure 4.5). The rainfall variability had influence on maize production; this may be associated with total amount of rainfall being above normal values leading to water logging and/or below average in the same area. Changes in the seasonal rainfall patterns may affect the total maize production despite the high total annual rainfall. The rainfall pattern is bimodal, namely, major (March to July) with June being the peak and minor (August to November) seasons. This rainfall seasonality supports both major and minor season maize farming as moisture is readily available throughout. This suggests that maize farmers in the district can cultivate in both seasons without fear of moisture availability to sustain production. This is in conformity with MoFA (2012) report that the district experiences two rainy seasons, in the same year.

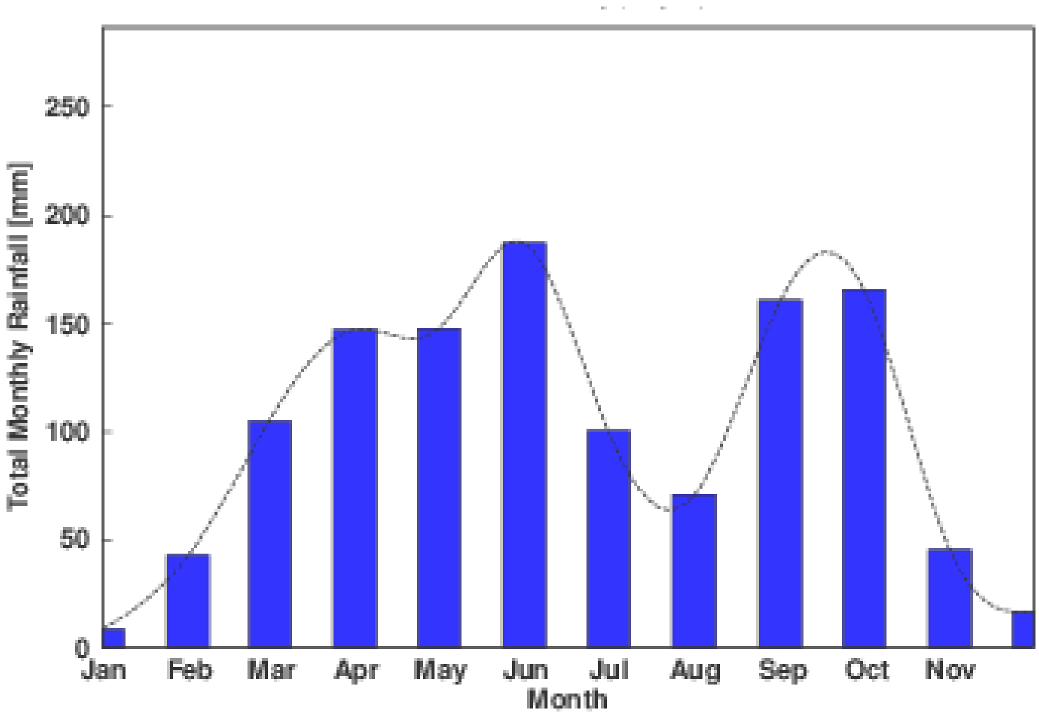

Figure 4.5: Rainfall seasonality

The year 2007 recorded the highest rainfall amount of 1458.4 mm while 1997 recorded the least of 923.3 mm. This suggests that rainfall amount is encouraging (as it is within the district mean annual rainfall range of 1250 mm and 1800 mm) and does support sustainable maize production. In order to clearly observe the rainfall pattern, a 5-year moving average was determined for the study duration. The 5-year moving average for the same period shows little variation in trend movement as depicted in Figure 4.6. This confirms the finding of Ayoade (2008), that the moving average has the characteristics of reducing the amount of variation in a dataset.

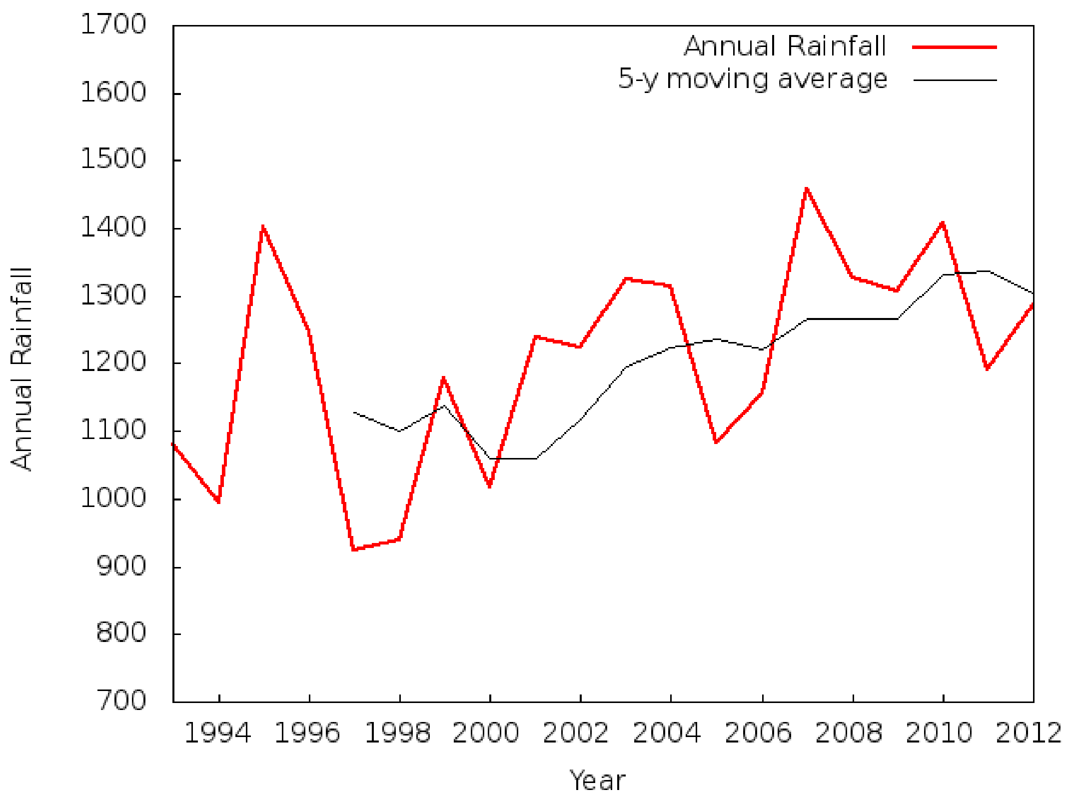

Figure 4.6: Annual rainfall and 5-year moving average

In order to determine the nature of the annual rainfall, thus whether a particular year was dry or wet, the rainfall anomaly indices were calculated. The negative rainfall anomalies signified that rainfall was less than the average annual rainfall for a particular place (Nagarajan, 2003). Figure 4.7 shows that 1997 experienced the most negative anomaly of -1.79 that signifies very dry year while 2007 experienced the most positive anomaly of 1.3 that shows the year was very wet.

When rainfall anomaly (X) is expressed as $-0.5 \leq X \leq 0.5$, thus, when X is greater than or equal to -0.5 and also less than or equal to 0.5, then the X is normal (Fox and Rockström, 2003). The X is considered dry and very dry year when is expressed as $-1.0 \leq X < -0.5$ and $X < -1$ respectively. On the other side, X is considered wet and very wet year when is expressed as $0.5 \leq X \leq 1.0$ and $X > 1.0$ respectively. As observed from the figure, most of the years after 2000 are either normal or wet while on or before 2000 is mostly dry.

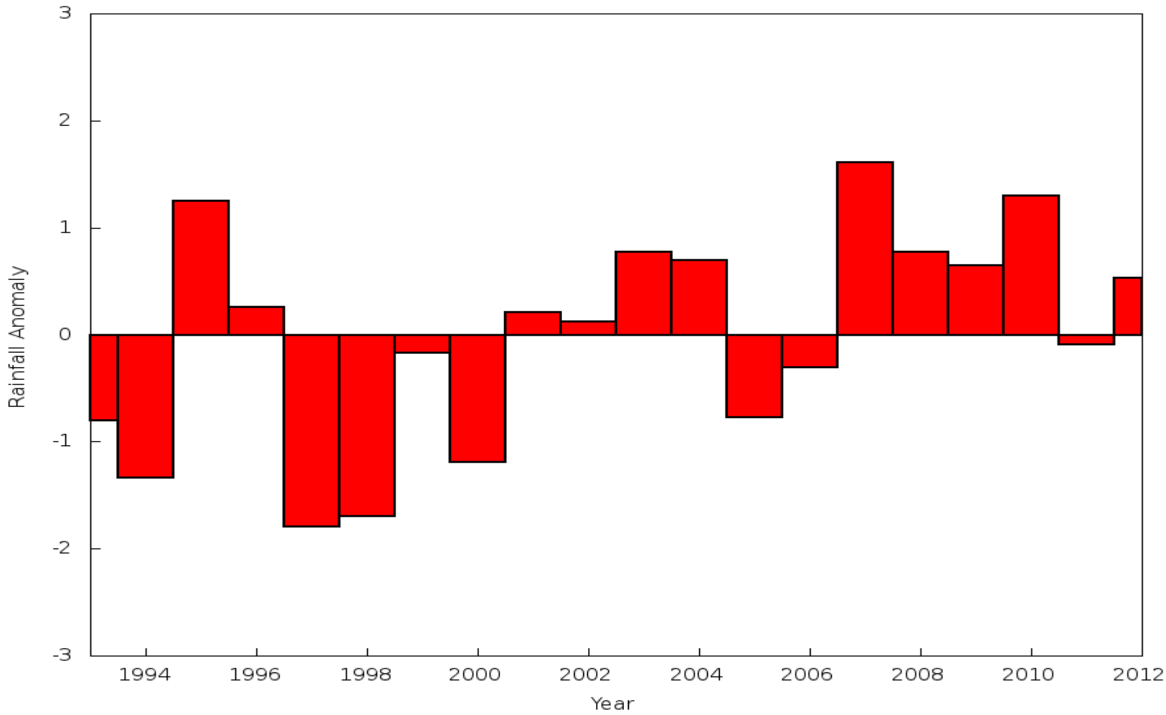

Figure 4.7: Annual rainfall anomaly

The onset dates for the rains in a specific zone was determined as the first date within a five-day period, where the least total amount of rainfall was recorded to be 20 mm. There was also not to be more than 7 days of dry period (without rain) between two rainy days. Any such date which did not meet these criteria was to be counted as a false start, hinting at a cessation date. Thus, an end of rain was determined as the last day before a long dry spell, when the water balance drops to zero. This definition is adopted from Dodd and Jolliffe (2001).

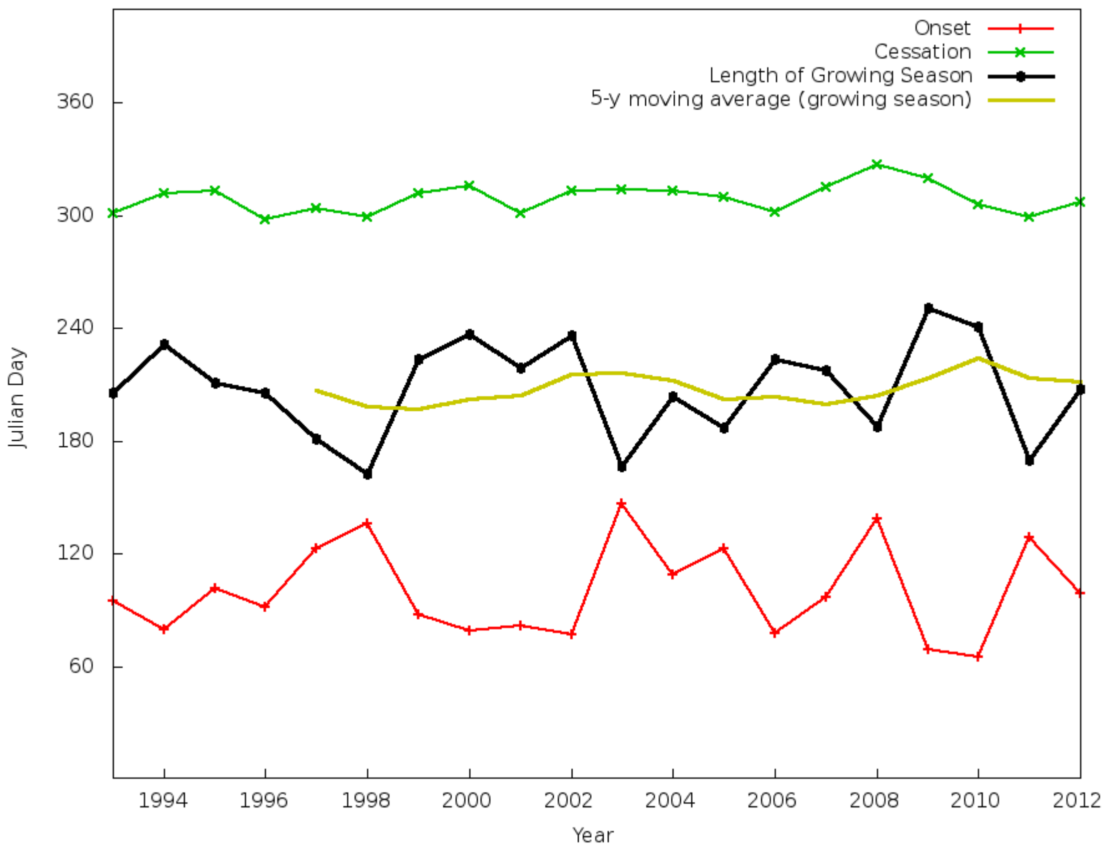

Figure 4.8: Onset, cessation and length of growing season and its 5-year moving average

Figure 4.8 shows that the earliest onset date for rainfall datasets occurred on 6th March (65 day) in the year 2010 and the latest onset occurred on 27th May (147 days) in the year 2003. While the earliest cessation date was computed to be 25th October (298 days) 1996 and the latest cessation happened on 23rd November (327 days) 2008.

The length of the growing season was computed for each rainfall season by counting the number of days from the onset date to the cessation date. The maximum length of the growing season was calculated to be about 251 days in 2009, and about 163 days in 1998 was the minimum. The 5-year moving average of growing season showed relatively no variation in its movement.

This suggests that there is correlation between the onset, cessation and the length of the growing season, where there was earliest onset, there was late cessation and longest length of the growing season and also vice versa. This is confirmed by Omogbai (2010), that wet years have early onset and late cessation dates, while the dry years recorded late onset of rains and early cessation dates respectively. On the whole the maize farmers in the study area got the planting period correct as they planted between March and May (see Figure 4.3). But the majority of maize farmers did not follow the scientific means of forecasting the rainfall onset and other variables before land preparation (Table 4.6 and Table 4.9) which may lead to the false start owing to the variable nature of tropical rainfall. The false start is said to happen when rainfall meeting the chosen criterion is followed by a long dry spell (Laux *et al.*, 2008). To sustain maize production, forecasting of planting dates can suggest whether a farmer should plant earlier or later than normal, whereas forecasting of cessation dates can help the farmer decide if they should store water to irrigate at the end of the season (should the rains end early).

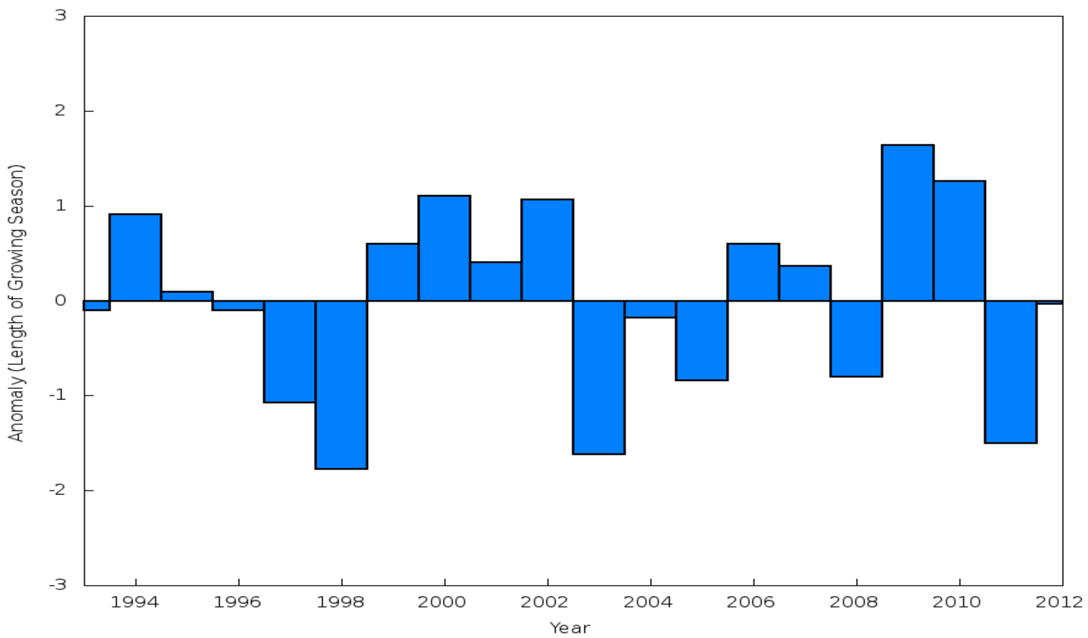

Figure 4.9: Anomaly of length of growing season

Figure 4.9 shows that the length of growing season anomaly (Y), is expressed as -0.5 $\leq$ Y $\leq$ 0.5. Thus, when is greater than or equal to -0.5 and also less than or equal to

0.5, then the Y is normal. The Y is considered dry and very dry year when it is expressed as $-1.0 \leq Y < -0.5$ and $Y < -1$ respectively. On the other side, Y is considered wet and very wet year when it is expressed as $0.5 \leq Y \leq 1.0$ and $Y > 1.0$ respectively.

The analysis shows that 1998 experienced the most negative anomaly of -1.77 that signifies very dry growing season while 2009 experienced the most positive anomaly of 1.64 that shows very wet season for growing. This suggests that 2009 growing season will support both major and minor seasons farming so when such information is given to maize farmers at the right time will enhance sustainability.

Rainfall variation

Rainfall influences land preparation time, planting period, growth and development of maize crop thus controlling both the present and future yield. In this part of the world, the sowing time is determined by the sufficiency of soil moisture of at least 20 mm (Laux *et al*., 2008) and rainfall is the major source of soil moisture. Table 4.50 shows that 73% of the farmers experienced some level of rainfall variability in the previous seasons farming whereas 27% of the respondents said they did not experience any rainfall variability. Figure 4.5 confirms the majority of maize farmers' experience.

Table 4.50: Respondents perception of 2011 major rainy season variation experienced

Rainfall Variation	Percent (%)
Yes	73.0
No	27.0
Total	100

Table 4.51 revealed that out of 146 respondents, 33.6% of them attributed the experienced rainfall variations to climatic change which happens to be a serious

environmental issue. About 20% linked the rainfall variability to perennial bushfires all over the district, 18.5% attributed it to deforestation and the rest indicated that it is due to our sin (12.3%).

Table 4.51: Reasons for experienced rainfall variations

Reasons	Percent (%)
Nature	15.1
Bushfires	20.5
Climate change	33.6
Due to our sin	12.3
Deforestation	18.5
Total	100

4.5 Tano North District Ministry of Food and Agriculture Officers perception on Sustainable Rainfed Maize Production and Environment

4.5.1 General Characteristics of the MoFA Staff

Gender distribution

The MoFA officers in the district consist of 70% male and 30% female as shown in Figure 4.10. This shows that there is disparity among the gender of staff which is not different from the maize farmers.

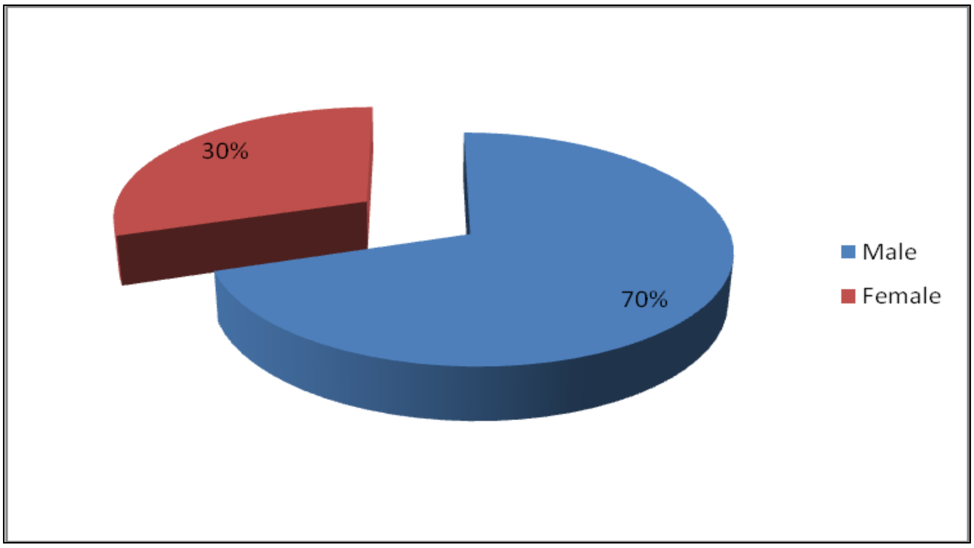

Figure 4.10: Gender distribution of the MoFA officials

Educational background of the MoFA officials

From the survey conducted, 65% of the respondents possessed Post-Secondary Certificates in Agriculture and 35% had completed Tertiary schools. This suggests that the MoFA staff in the study area are well trained and competent to professionally handle challenges pertaining to maize production and agriculture in general.

Years in service at MoFA

According to respondents among MoFA staff, 55% of them have served for more than five years and 45% have served less than five years (Table 4.52). Thus, majority of the MoFA officers are experienced to deal with agricultural challenges in the district.

Table 4.52: Years in service

Years in service	Frequency	Percentage (%)
1 - 5	9	45
6 - 10	5	25
11 - 15	3	15
> 15	3	15
Total	20	100

4.5.2 Soil, inputs and extension supports

The MoFA staff interviewed indicated that the soil in the district is favourable for maize production. This confirms MoFA (2012) report that Tano North District soil consists basically of forest orchrosols and generally, the various types of soils in the District are fertile. The abundant arable land found in the District is favourable for the cultivation of a wide range of food and cash crops. Hence it is left for the maize farmers to adhere to best agronomic practices.

The survey revealed that 15% of the respondents were offered farming inputs from MoFA either free (5%) or subsidized (10%) whereas 85% of them did not (Table 4.53). Again according to the MoFA staff, maize farmers do not receive any financial assistance through their office as pertains nationwide. Access to credit was difficult and farmers' sources of funding are from friends and retailers (Table 4.31). Farmers are poor and have limited access to market and credit. Thus farmers are unable to buy the needed inputs like fertilizers, improved maize varieties, and payment for labour that will boost their production.

Table 4.53: Inputs supply and payment

Inputs Payment	Percent (%)
Free	5.0
Subsidized	10.0
Full amount	0.0
No input	85.0
Total	100

Extension education by MoFA

According to the MoFA extension staff, farmers are given extension education in the following areas.

a. Soil fertility management
b. Climate
c. Yield and storage practices and
d. Use of agro-chemicals.

Accessibility of agricultural extension services

The survey revealed that access to agricultural extension services by the maize farmers in the study area is satisfactorily (Table 4.54). This suggests that farmers are likely to apply their own ideas and may not have access to improved technologies.

The poor accessibility of extension services can contribute to low yield in the study area. This is in accordance with the findings of Bokor (2005) that, access to extension services is the only means through which the desired transformations can be brought in agricultural land productivity of the farming community. It is in this perspective that technology development (through research) and technology transfer (through extension education) have been identified as key inputs for developing and sustaining productivity. Yields are the eventual consequences of developmental efforts, and extension impact would be reflected more in yields than in other measures.

Table 4.54: Accessibility of Agricultural extension services

Accessibility	Percent (%)
Poor	0.0
Satisfactory	100
Good	0.0
Total	100

4.5.3 Rainfall pattern, yield and pests and diseases assessment

According to MoFA officials, the rainfall pattern in the district for the past farming seasons has been encouraging since there has not been any drought. They confirmed that there has been even distribution of rainfall in the district. This suggests that the backbone factor of rainfed farming is not lacking and that provision of other factors will sustain maize production in the study area.

Table 4.55: Rainfall pattern

Rainfall pattern	Percent (%)
Good	45.0
Average	55.0
Poor	0.0
Total	100

Yield assessment

MoFA staff assessed the district maize yield as average with reasons given in Table 4.56, which confirms the assertion of Heisey and Norton (2007) that most farmers do not adopt the additional production practices needed to sustain yield improvement. This is particularly noticeable with respect to practices for maintaining and enhancing soil fertility, even though the shortening of the bush fallow rotation as a consequence of population pressure has made poor soil fertility the major constraint to raising productivity in many areas.

Table 4.56: MoFA staff reasons for the average crop yield in the district

Reason	Frequency	Percent (%)
Continuous cropping on the farm land	5	25.0
Non-application of fertilizer	3	15.0
Late planting habit of some farmers	2	10.0
Non application of insecticide	1	5.0
Difficulty in acquiring land for maize farming	1	5.0
Farmers being more interested in cash crops (cocoa)	5	25.0
Lack of government support in terms of funds and inputs	3	15.0
Total	20	100

Maize is a heavy consumer of fertilizer, leading fertilizer demand in industrialized countries among major cereals, and the second most heavily fertilized crop on a global scale, after potatoes (Heisey and Norton, 2007). Additionally, farmers may grow improved varieties without fertilizer and even where fertilizer is used, it is often used inefficiently.

Common pests and diseases and their management in the district

Pests and diseases are believed to have a detrimental effect on maize yield if they are not well-managed. The common pests/diseases and their management as mentioned by MoFA officials in the district are as presented in Table 4.57.

Table 4.57: Pests and Diseases management

Pests/Diseases	Management
Weevils	Pesticide application
Birds	Erection of scare crows
Grasscutter	Traps setting
Termites	Good cultural practice
Stem borer infestation	Insecticide application
Nitrogen deficiency	Nitrogen fertilizer application
Green mould	Good cultural practice and drying

4.5.4 MoFA staff perception of environmental problems resulting from farming practices

The activities of maize farming according to the MoFA officials in the district raises core environmental issues. These start with land preparation to storage. The activity and its corresponding environmental problems are tabulated in Table 4.58.

Table 4.58: Selected farming activity and its corresponding environmental problems

Activity	Environmental problems
Slash and burn	Degrading the top soil, causing erosion and destruction of both macro and micro organism
Continuous cropping	Depleting soil nutrients leading to infertility of land
Herbicide application	Destroying of micro organisms
Tree felling	Causing deforestation and poor rainfall pattern

Sustainability of rainfed maize production in the district

According to MoFA officials in the district, rainfed maize production is sustainable due to the moderate climatic conditions such as good (45%) to average (55%) rainfall. Again, availability of farm land and ready market for the farm produce would always motivate the farmers to go into maize farming. Moreover, the presence of MoFA officials to help resolve most of the farmers concerns is good for sustainability.

The MoFA officials' assessment of various sustainability indicators are as shown in Figure 4.11. Most of the factors (ES)- Extension services; (CP)- Cultural practices; (PDM)- Pests and diseases management; (CY)- Crop Yield, (CHS)- Crop harvest and storage; and (FACEP)- Farming activities and corresponding environmental problems were assessed as average and used as key.

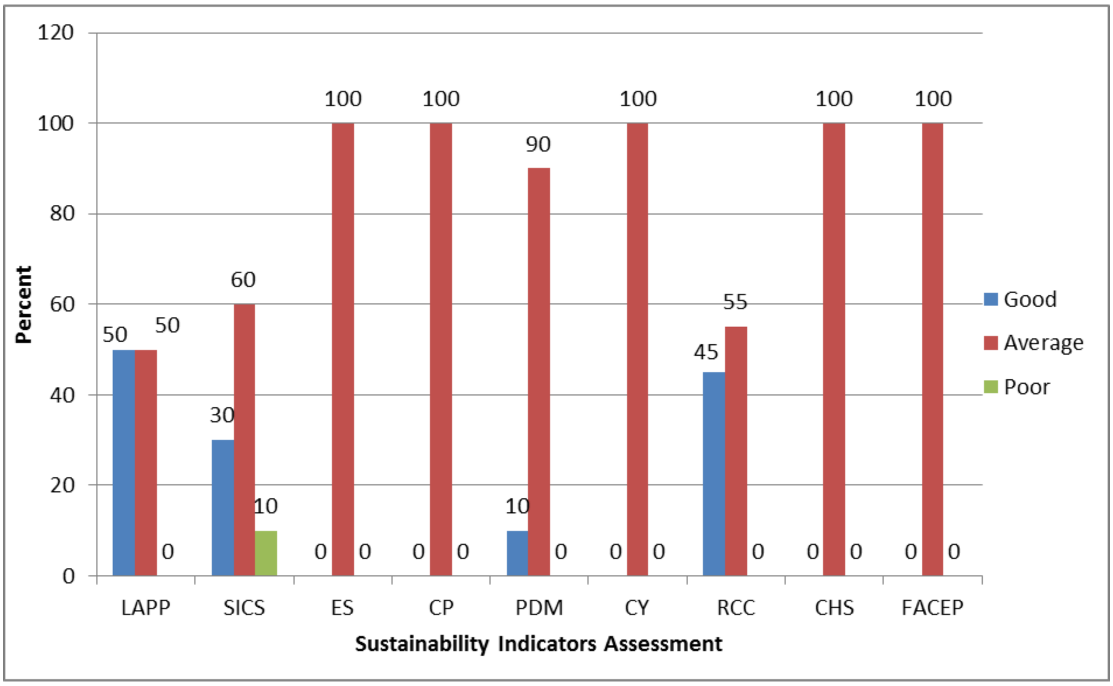

Figure 4.11: Sustainability assessment of rainfed maize production by MoFA staff

Explanation of some abbreviations

LAPP- Land acquisition, preparation and planting; SICS- Soil and inputs/credits support; ES- Extension services; CP- Cultural practices; PDM- Pests and diseases management; CY- Crop Yield; RCC- Rainfall and climatic conditions; CHS- Crop harvest and storage; and FACEP- Farming activities and corresponding environmental problems.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Rainfed maize production in the Tano North District is mainly done by non-formally educated males (73.5%) who are 40 years and above. Majority of maize farmers do not own land (71.5%) and obtain access through shared agreement such as *abusa*.

The current maize production practices that involves slash and burn or herbicide land preparation, recycling of seeds from farmer's own farm, and random sowing pattern coupled with low input and poor access to extension services lead to low yields which is a key attribute of unsustainability.

Farmers have little knowledge in soil fertility and crop residues management as well as the effect of herbicides and pesticides application on the environment. Also they practice continuous cropping depletes soil nutrients causing decline in soil fertility and cutting down trees indiscriminately causes deforestation. The maize farmers experience both pre-harvest and post-harvest losses.

Generally, the rainfall is bimodal with seasonal variability. The year 2007 recorded the highest rainfall amount of 1458.4 mm and the least of 923.3 mm was recorded in 1997. The year 2010 was very wet as it experienced the most positive anomaly of 1.3 while 1997 was very dry year as it experienced the most negative anomaly of -1.79. It was observed that most of the years after 2000 were either normal or wet while on or before 2000 was mostly dry. There was correlation among the onset, cessation and the length of the growing season. Where there was earliest onset, there was late cessation and longest length of the growing season and also vice versa and this information is very key to forecasting maize production that will enhance sustainability.

Ministry of Food and Agriculture (MoFA) staff in the district is male dominated (70%), well educated with majority having worked for more than five years (55%). They perceived maize yield to be average. Farmers are more interested in cash crops (eg. Cocoa), do not apply fertilizer, among others. MoFA staff perceive environmental problems resulting from farming practices as due to the slash and burn (degrading the top soil), herbicides and pesticides application (destroying of micro organisms). MoFA officials offer extension education to maize farmers on soil fertility management, weather and climate, yield and storage. According to the MoFA staff, rainfed maize production in the district is sustainable due to moderate climatic conditions availability of farm land, ready market for farm produce and above all, the presence of MoFA officials to help resolve most of the farmers' concerns.

5.2 Recommendations

In the light of the findings of this study, it is recommended that, yield gap analysis for maize be undertaken to determine the major constraints militating against increasing maize yield in the district.

To reduce the risk associated with seed recycling by farmers, research, policies and regulations in the seed sector should be looked at.

To ensure that the effect of rainfall variability on maize production is reduced and maize yield is generally enhanced and sustained in the study area, the Ghana Meteorological Agency in collaboration with MoFA should establish meteorological stations in the district to better help forecast dates of rainy season onset and cessation, length of rainy season and annual number of rain days.

Government should employ more Agricultural Extension Officers (AEAs) with adequate resources to educate maize farmers on environmentally sustainable maize production practices. Provision of government subvention on farm inputs shall be helpful as it is being done for cocoa farmers. This can be in the form of subsidies, waving of import duties and tax reduction on maize production inputs.

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APPENDICES

APPENDIX 1

QUESTIONNAIRE

TOPIC: SUSTAINABILITY ASSESSMENT OF RAINFED MAIZE PRODUCTION SYSTEMS IN THE TANO NORTH DISTRICT

Dear respondent,

This questionnaire is to help Mr. Afful Acheampong Ebenezer, a postgraduate student of KNUST, complete his project on the aforementioned topic. The information you will provide would be treated with the utmost confidentiality and it is intended for academic purposes only. Thank you.

A. PERSONAL DETAILS

Name:……………………………………………………………………………………

Sex: Male ( ) Female ( )

Education: ………………………………………………..

Age: …………………………………………………

Years in farming:……………………………………………

B. LAND PREPARATION

What indicators determine the time of land preparation in the major season?

…………………………………………………………………………………

…………………………………………………………………………………

What indicators determine the time of land preparation in the minor season?

…………………………………………………………………………………

Time of land preparation in the minor season (please tick)

Month of land preparation

June ( )

July ( )

August ( )

Is this the normal month in all seasons? (Please tick) Yes ( ) No ( )

Which week of the chosen month? (Please tick)

1st week ( )

2nd week ( )

3rd week ( )

4th week ( )

Is this the normal week in the seasons? (Please tick) Yes ( ) No ( )

Time of land preparation in the major season (please tick)

Before Easter ( )

After Easter ( )

Month of land preparation

February ( )

March ( )

April ( )

Is this the normal month in all seasons? (Please tick) Yes ( ) No ( )

Which week of the chosen month? (Please tick)

1st week

2nd week

3rd week

4th week

Is this the normal week in all seasons? (Please tick) Yes ( ) No ( )

Method used in land preparation (Please tick)

Slash and burn ( )

Slash and burn/Herbicide ( )

Weeding with tractor ( )

Much tillage ( )

Zero tillage ( )

Others. ( ) ……………………………………………

Is this method applied in all seasons (please tick) Yes ( ) No ( )

Which simple farming tool do you employ in the land preparation?

Machete ( )

Hoe ( )

Herbicide ( )

Animal traction ( )

If Herbicide, what do you know about it to the environment?

………………………………………………………………………………………

Do you prefer the lowlands to highlands for maize cropping? Yes ( ) No ( )

Give reason(s) to your answer …………………………

Are you involved in the following? (Please tick)

Ploughing Yes ( ) No ( )

Harrowing Yes ( ) No ( )

Ploughing and harrowing Yes ( ) No ( )

Herbicide application Yes ( ) No ( )

Human Weeding Yes ( ) No ( )

If Herbicide, what do you know about it to the environment? …………………………………………………………………………………

Do you raise ridges or seedbeds for the maize plants? Yes ( ) No ( )

Give reasons:.……………………………………………….

How much do you spend on land preparation? Give estimated amount in Ghana Cedis (GH¢) per acre …………………………………………………

Where do you get that amount from?

Government ( )

Personal Loan ( )

Personal Savings ( )

Plough back ( )

Others ( ) Specify ………………………………………………

Do agricultural extension officers visit you during land preparation?

Yes ( ) No ( )

C. SEED VARIETY AND PLANTING PATTERN

Seed Variety (please tick)

Abeleehi ( )

Local maize ( )

Mamaba ( )

Obaatanpa ( )

Okomasa ( )

Do you choose your seeds according to the farming season? Yes ( ) No ( )

Please explain your answer ……………………………………………………

…………………………………………………………………………………

Is this variety planted in all seasons (please tick) Yes ( ) No ( )

If any other variety please specify ………………

…………………………………………………………………………………

Maturity day of selected variety ……………………………….

Days to tasselling of selected variety ………………………………

Days to silking of selected variety/type……………………………

Reason for choosing that variety/type ………………………………

Planting period in the major season (please tick)

Before Easter ( )

After Easter ( )

Planting month (please tick)

March ( )

April ( )

May ( )

Which week of the chosen month (please tick)

1st Week ( )

2nd Week ( )

3rd Week ( )

4th Week ( )

Have there been any reason(s) for changing the planting month? (tick)

Yes ( ) No ( )

Reasons if there is a change (please tick)

Changing rainfall pattern ( )

Type of variety ( )

Specify if any other reason.

……………………………………………………………………………………

Planting period in the minor season (please tick)

July ( )

August ( )

September ( )

Which week of the chosen month? (please tick)

1st Week

2nd Week

3rd Week

4th Week

Is there any change in planting time from previous seasons? (Please tick)

Yes ( ) No ( )

Reasons if there is a change (please tick)

Rainfall pattern ( )

Type of variety ( )

Specify if any other reason ………………………………

……………………………………………………………………………………

Planting Pattern (please tick)

Rows ( )

Random ( )

Planting distances if in rows

Distance between rows ………………………………………………

Distance within rows ………………………………………………

Number of seeds planted per hill in the major season (please tick)

2 ( )

3 ( )

4 ( )

Number of seeds planted per hill in the minor season (please tick)

2 ( )

3 ( )

4 ( )

Does the farming season influence the number of seeds planted? Yes ( ) No ( )

If yes, please explain and give reasons for choice of number of seeds

……………………………………………………………………………………

Is there thinning if 3 or 4 seeds are planted? Yes ( ) No ( )

Seeds germination

All seeds germinated ( )

Almost all seeds germinated ( )

Few seeds germinated ( )

Is this the germination pattern in all seasons? (please tick) Yes ( ) No ( )

If no, what is the reason? …………………………

……………………………………………………………………………………

Tools used in planting (please tick)

Line and stick ( )

Line and cutlass/Machete ( )

Dibbler ( )

Seed planter ( )

Jab planter ( )

Source of seeds (please tick)

From previously harvested grains ( )

From accredited agents e.g. Agrochemical shops ( )

From neighbours ( )

Do you conduct germination test on the seeds before planting? Yes ( ) No ( )

What cropping system do you practice?

Mono cropping ( )

Mixed cropping ( )

None ( )

Give reason(s) for your answer: ……………………………

Where do you keep the surplus seeds which are left …………

Do you sprinkle chemicals on the seeds before planting? Yes ( ) No ( )

If yes, why? ……………………………………

Name the chemicals: ………………………………

How is the container of the chemicals handled? …………………

D. WEED CONTROL MECHANISM

How many times do you weed your farm in the major season?

…………………………………………………………………………………

How many times do you weed your farm in the minor season?

…………………………………………………………………………………

Time of weeding

After planting (please tick)

1st Week ( )

2nd Week ( )

3rd Week ( )

4th Week

Is this the normal practice in all seasons? (please tick)**.** Yes ( ) No ( )

After tasselling (please tick)

1st Week ( )

2nd Week ( )

3rd Week ( )

4th Week ( )

Is this the normal practice in all seasons? (Please tick.) Yes ( ) No ( )

Method used in weed control?

Biological Yes ( ) No ( )

Chemical Yes ( ) No ( )

Mechanical Yes ( ) No ( )

If chemical, what type is used? ……………………………………

Is this the normal type used in all seasons? (please tick). Yes ( ) No ( )

If mechanical, which of the following do you employ?

Cutlass/Machete ( )

Hoe ( )

Tractor mounted implement ( )

Hand pulling ( )

Is this the normal tool/implement used in all seasons? Yes ( ) No ( )

E. PEST AND DISEASE CONTROL MECHANISM

Do you employ any protective/preventive measures? Yes ( ) No ( )

If yes, Please specify them ………………………

Mechanism employed. (please tick)

Biological ( )

Chemical ( )

Mechanical ( )

If chemical, what type is used? …………………………………………

What time? ……………………………………………………………

If biological, is it intercropped with other crops? Yes ( ) No ( )

If yes, what type of crop? ……………………………………………

Does the farming season influence disease and pest control? Yes ( ) No ( )

Please explain your answer. …………………………………………………

Do you plant leguminous crops with the maize? Yes ( ) No ( )

If yes, what type is planted? …………………………………

When is the leguminous crop planted? (please tick)

Before the maize is planted ( )

After the maize has been planted ( )

Please give the specific time and the context in which it is planted.

……………………………………………………………………………………

Is it planted by any of the following? (please tick)

Within rows ( )

Between rows ( )

What is the purpose of the leguminous crops planted? (please tick)

For food ( )

For pest combating ( )

For money ( )

As weed suppression ( )

As feed for livestock ( )

As a nutrient supplement ( )

F. FERTILIZER TYPE AND APPLICATION

Do you apply fertilizer on your farm? Yes ( ) No ( )

If no, why? …………………………………….

If yes, what type is applied? Organic ( ) Inorganic ( )

Method of application. (Please tick)

Broadcasting ( )

Placement ( )

Ring ( )

Is this the normal method used in all seasons? (Please tick) Yes ( ) No ( )

Number of times of fertilizer application. (Please tick)

Once ( )

Twice ( )

Is this the normal practice (Please tick) Yes ( ) No ( )

Time of application

After planting (Please tick)

1st week ( )

2nd Week ( )

3rd Week ( )

To tasselling (Please tick)

1st week ( )

2nd Week ( )

3rd Week ( )

Is this the normal practice (Please tick) Yes ( ) No ( )

Does the farming season influence the type and application of fertilizer?

Yes ( ) No ( )

If yes, how does it? ………………………

Observed time to tasselling. ………………………

Is this the normal time in all seasons? (Please tick) Yes ( ) No ( )

Observed time of silking. …………………………

Is this the normal time in all seasons? (Please tick) Yes ( ) No ( )

Observed time to maturity. ………………………

Is this the normal time in all seasons? (Please tick) Yes ( ) No ( )

G. YIELD, TRANSPORTATION, STORAGE AND INCOME

What is the size of your farm? ……………………………

Is this the normal size of your farm in all seasons? (Please tick) Yes ( ) No ( )

Obtained yield. (Please tick)

High ( )

Low ( )

Crop failure ( )

Is this the yield normally obtained? (please tick) Yes ( ) No ( )

Reasons due for low yield or crop failure.

Rainfall pattern ( )

Pests and diseases ( )

Germination failure ( )

What is your farm yield after harvesting? (Please tick)

Below 5 mbag/acre (0.63 t/ha) ( )

5 to 10 mbag/acre (0.63 to 1.25 t/ha) ( )

10 to 15 mbag/acre (1.25 to 1.88 t/ha ( )

Above 15 mbag/acre (1.88 t/ha) ( )

Please specify if any other. …………………………

Are you aware of what yield you are supposed to harvest? Yes ( ) No ( )

Do you encounter pre-harvest losses? Yes ( ) No ( )

If yes, is it through any of the following? (Please tick)

Pest (Rodents) attack	Yes ( ) No ( )
Diseases	Yes ( ) No ( )
Termites attack	Yes ( ) No ( )
Lodging	Yes ( ) No ( )

Theft Yes ( ) No ( )

Specify, if any other…………………………………………………………….

Do you encounter post-harvest losses? Yes ( ) No ( )

If yes, is it through pests' infestation? Yes ( ) No ( )

Specify if any other. ………………………………………………

What means do you employ in transporting maize?

Family support ( )

KIA truck ( )

Bicycle ( )

Other ………………………………………………………….

Is the maize husk removed before transporting? Yes ( ) No ( )

If yes, how do you manage the husks? ……………

Where do you store your maize?

Maize barn ( )

Cribs ( )

Sack bags ( )

Other(s) ( ) Specify

………………………………………………………………………….

Do you treat before storing? Yes ( ) No ( )

If yes, what method of treatment?

Chemical ( )

Biological ( )

Other (s) ( ) Specify…………………………………….

If chemical, mention the name ………………………………

H. RAINFALL PATTERN AND GENERAL CLIMATIC VARIATION

Was rainfall different from normal in the following months? (Please tick)

August Yes ( ) No ( )

September Yes ( ) No ( )

October Yes ( ) No ( )

November Yes ( ) No ( )

Have these variations in rainfall been experienced in the previous seasons?

Yes ( ) No ( )

If no, why this time? …………………………………

Do you experience bush fires? Yes ( ) No ( )

If yes, who causes it? …………………………………………

Do you experience flooding in your area? Yes ( ) No ( )

If yes, what causes it? ………………………………………………

I. GENDER AND LAND ACQUISITION

Among the sexes who dominates in maize production? Male ( ) Female ( )

Give reasons for the answer given. ……………………………

Should female participation be encouraged? Yes ( ) No ( )

Do you have your own land? Yes ( ) No ( )

If no, how do you acquire one?

Abunu ( ) *Abusa* ( ) Hired ( ) Other ( ) Specify ……

Is land difficult to acquire? Yes ( ) No ( )

J. FINANCIAL AND INPUTS SUPPORT

Do you receive any financial assistance from ……

Government	Yes ( )	No ( )
Bank	yes ( )	No ( )
Friend	yes ( )	No ( )

Others ( ) Specify……………………………

Do you receive any agric inputs? Yes ( ) No ( )

If yes, from where and what kind(s) of inputs? ………………

K. CROP RESIDUE MANAGEMENT

Where do you keep the left over stalks of the maize plants?

Left on the farm ( )

Send to house ( )

Other(s)

Specify…………………………………………………………………

What benefits do you get from the stalks?

Feed residue to livestock ( )

Plough residues under ( )

As fire wood ( )

Others ( ) Specify ……………………………

L. EXTENSION AND OTHER ACTIVITIES

How accessible are the agric extension services? (Please tick)

Excellent ( )

Very good ( )

Good ( )

Average ( )

Poor ( )

Is your farm involved in any research activity? (Please tick) Yes ( ) No ( )

If yes, how often?

Once a season ( )

Twice a season ( )

Have you been involved in any educational as in training or workshops to raising your knowledge and skills in the farming practices you employ? Yes ( ) No ( )

If yes, how many times in a season? (Please tick)

Once a season ( )

Twice a season ( )

How beneficial is/are it/they to you? (Please tick)

Excellent ( )

Very good ( )

Good ( )

Average ( )

Poor ( )

Do you receive any extension support services from MOFA? Yes ( ) No ( )

If yes, please tick the following appropriately.

A. Fertilizer application ( )
B. Planting techniques ( )
C. Chemical application ( )
D. Seed storage ( )
E. Other(s) specify …………………………………………………

Do you receive recommended seeds supply from extension support services unit? Yes ( ) No ( )

If yes, what is/are the conditions attached? A. Free ( ) B. On credit ( ) C. Other specify …………………………………………

Have you received any form of advice on climatic and weather changes/pattern in your farming area from MOFA? Yes ( ) No ( )

If yes, how many times in a season? A. Once B. Twice C. Other specify …………..

Where are the resource persons who conduct you through these workshops or training from? (Please tick)

The local community ( )

The Municipal Directorate of the Food and Agric Ministry ( )

The Regional Directorate of the Food and Agric Ministry ( )

Non – Governmental Organizations ( )

………………………………………………………………………………

Specify if any other. ……………………………

………………………………………………………………………………

THANK YOU FOR YOUR TIME AND ATTENTION.

APPENDIX 2

QUESTIONNAIRE FOR TANO NORTH MINISTRY OF FOOD AND AGRIC OFFICERS

TOPIC: SUSTAINABILITY ASSESSMENT OF RAINFED MAIZE PRODUCTION SYSTEMS IN THE TANO NORTH DISTRICT

Dear respondent,

This questionnaire is to help Mr. Afful Acheampong Ebenezer, a postgraduate student of KNUST, complete his project on the aforementioned topic. The information you will provide would be treated with the utmost confidentiality and it is intended for academic purposes only. Thank you.

A. PERSONAL DETAILS

Name:……………………………………………………………………………

Sex: Male ( ) Female ( )

Education: ……………………………… Position:…………………

Contact (Phone/E-Mail): ……………………………………………

Years in the service:……………………………………………

B. QUESTIONS

1. Is the soil in the district favourable for sustainable maize production?
   A. Yes ( ) B. No ( )
2. If No, what should be done? ....
3. Do maize growers get any financial assistance through your office? A. Yes ( ) B. No ( )
4. If Yes, how much per acre of land………………………………………
5. Do you give farming inputs to the maize growers? A. Yes ( ) B. No ( )
6. If Yes, how much do they pay? A. Free B. Subsidized amount C. Full amount D. Other………….
7. Do you render climatic and weather advisory services to the maize production farmers in the district? A. Yes ( ) B. No ( )
8. Give reason(s) to your answer in (7) please………………………
9. Are the farmers educated on the yield storage management practices? Yes( ) No ( )
10. Please give reason(s) to your answer in (9)
    ……………………………………………………………………………………
11. Are the farmers educated on soil fertility management? Yes ( ) No ( )

12. Please give reason(s) to your answer in (11)

    …………………………………………………………………………………

    …………………………………………………………………………………

13. Assess Agric Extension Services rendered to the maize farmers in the district.

    A. Poor B. Satisfactory C. Good D. Other…………………

14. Give reason(s) to your answer in (13) please …………………………………..

    ……………………………………………………………………………………..

15. Are the farmers educated on how to handle agro-chemicals on their field? A. Yes B. No

16. Give reason(s) to your answer in (14) please

    …………………………………………………………………………………

    …………………………………………………………………………………

17. Assess the yields of maize crop in the district. A. Poor B. Average C. Good D. Other……………

18. Explain your answer please

    ....

    …………………………………………………………………………………

19. Assess rainfall pattern in the district. A. Poor B. Average C. Good D. Other…………

20. Comment on your answer in (19)

    ……………………………………………………………………………..

21. Give the common diseases which mostly affect maize crops' development in the district…………………………………

22. Give the common pests which mostly affect maize crops' development in the district

    …………………………………………………………………………………

23. How do you manage maize pest and disease?

    …………………………………………………………………………………

24. Do the activities of the rainfed maize producers in the district cause environmental issues which should be addressed? A. Yes B. No

25. If Yes, mention the activity and its corresponding issue in the table below:

ACTIVITY	ENVIRONMENTAL ISSUE
a.	
b.	
c.	
d.	
e.	

26. Please assess sustainability of the rainfed maize production in the district. A. Poor B. Average C. Good D. Other ……………………………………..
27. Give reason(s) to your answer in (26) please …………………

…………………………………………………………………………………

Thank you for your time and immense contribution.

Note: Please you may circle or tick the correct option.

APPENDIX 3

RAINFALL DATA

Year	Onset	Cessation	Growing Season	5-yr Moving Average (Length of Growing Season)	Anomaly (Growing Season)	Annual Rainfall	Anomaly (Annual Rainfall)	5-yr Moving Average (Annual Rainfall)
1993	95	301	206	-	-0.1	1080.1	-0.8	-
1994	80	312	232	-	0.91	995.3	-1.34	-
1995	102	313	211	-	0.09	1401.6	1.25	-
1996	92	298	206	-	-0.1	1246	0.26	-
1997	123	304	181	207.2	-1.07	923.9	-1.79	1129.4
1998	136	299	163	198.6	-1.77	938.3	-1.7	1101
1999	88	312	224	197	0.6	1178.3	-0.17	1137.6
2000	79	316	237	202.2	1.1	1017.6	-1.19	1060.8
2001	82	301	219	204.8	0.4	1238.2	0.21	1059.3
2002	77	313	236	215.8	1.06	1223.6	0.12	1119.2
2003	147	314	167	216.6	-1.62	1325.8	0.77	1196.7
2004	109	313	204	212.6	-0.18	1314.8	0.7	1224
2005	123	310	187	202.6	-0.84	1083.9	-0.77	1237.3
2006	78	302	224	203.6	0.6	1156.3	-0.31	1220.9
2007	97	315	218	200	0.36	1458.4	1.61	1267.8
2008	139	327	188	204.2	-0.8	1326.6	0.77	1268
2009	69	320	251	213.6	1.64	1306.8	0.65	1266.4
2010	65	306	241	224.4	1.26	1408.9	1.3	1331.4
2011	129	299	170	213.6	-1.5	1190.7	-0.09	1338.3
2012	99	307	208	211.6	-0.03	1288	0.53	1304.2