ASSESSMENT OF RAINFALL AND TEMPERATURE AS CLIMATE VARIABILITY INDICATORS AND THEIR IMPACT ON MAIZE (*Zea mays* L.) YIELD IN THE EJURA SEKYEDUMASE DISTRICT: FARMERS' PERCEPTION, METEOROLOGICAL DATA.

By

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DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

This study assessed the perception of farmers in the Ejura Sekyedumase District on Climate variability and how it has affected agriculture from 1993 to 2006. Opinions from 150 respondents selected through a stratified simple random sampling were analyzed using descriptive statistics. Meteorological data was analyzed using INSTAT PLUS v3.33 e whilst grain yield and perception data were analyzed using and Statistical Package for Social Scientist (SPSS) and the results showed that most of the farmers were within the age groups of 31-40 years (34.7%) and 41-50 (30.0%) and most (84.0%) farmers had had formal education.

Except for temperature changes which had been noticed by only 9 -14% of the farmers, over 75% had noticed changes in rainfall and drought. Lack of access to water was the main factor inhibiting adapting to other methods of watering crops. Lack of access to credit, information on weather and alternative farming practices were the others. Analysis of the areas meteorological data did not strongly support the farmers' perception. The suitable planting time from the analysis of precipitation data in the area is 8th April for the major season and 31st August for the minor season. The mean dates for end of rains were 10th July and 2nd November for the major and minor seasons respectively. Out of the considered meteorological elements, only annual precipitation was found to have considerable influence on the grain yield.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DOY	Day Of Year
EA	Enumeration Area
FAO	Food and Agriculture Organization
CFAR	Climate Forecasting for Agricultural Resources
IPCC	Intergovernmental Panel on Climate Change
LAI	Leaf Area Index
Lat	Latitude
Long	Longitude
Ha	Hectre
K.M.A.	Kumasi Metropolitan Assembly
MOFA	Ministry of Food and Agriculture
PPMED	Policy Planning Monitoring and Evaluation Department
SD	Standard Deviation

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CHAPTER ONE

1. INTRODUCTION

Climate variability has a large influence on the lives of the communities in Ghana. The climatic elements with the largest influence are rainfall and temperature. Rainfall is, however, the single most important element for the activities of the many of the Ghanaian communities who depend on rain-fed subsistence agriculture for their livelihood.

Food security, particularly in developing countries, remains a challenge. Nearly half of the world's population (2.9 billion people) live on less than $2 a day (World Bank, 2001) and food production has to double in the next 35 years if future needs are to be met (Watson, 2001). This challenge is made worst by the adverse effect of predicted climate change in most food insecure developing countries (Rosenzweig and Parry, 1994). Given the large body of research that has been done to quantify the contributions of crop productivity (Evenson and Gollins, 2003a; Evenson and Gollin, 2003b), it is known that factors such as modern varieties of crops, increasing input use, and better farm management contribute greatly to crop growth and yield.

However, our knowledge of the impact of climate on crop productivity remains quite uncertain. While many researchers have evaluated the possible impact of global warming on crop yields using mainly indirect crop simulation models (Reilly *et al.*, 2003), there are relatively few direct assessments of the impact of observed climate change on past crop yield and growth except for a few studies (Lobell and Asner, 2003; Peng *et al.*, 2004). In a recent study, Peng *et al.* (2004) reported that rice yields decline with higher night temperatures. Lobell and Asner (2003) showed that corn and soybean yields in the US could drop by as much as 17 percent for each degree increase in the growing season temperature.

The impacts on people's livelihoods will be greatest in the tropics and subtropics, and particularly in Africa, mainly because many poor smallholders depend on agriculture and have few alternatives (IPCC, 2001b).

Gu (2003), stated that though climate is the major uncontrollable factor that influences crop development, it is difficult to separate this influence from other factors such as the increased use of modern inputs and intensified crop management that were introduced during the Green Revolution.

The adoption of modern varieties and the increased use of irrigation and fertilizers during the Green Revolution dramatically increased crop yields all over the world (Evenson and Gollins, 2003b; Rosegrant and Cline, 2003). The Green Revolution enabled food production in developing countries to keep pace with population growth (Conway and Toenniessen, 1999). Crop yield growth has slowed since 1990 (Evenson and Gollins 2003b) but continued crop yield increases are required to feed the world in the 21st century (Rosegrant and Cline 2003) given the continuing decline of areas suitable for grain production due to urbanization and industrialization.

1.1 PROBLEM STATEMENT

Climatic variability refers to inter-annual fluctuations. Basically stated, the weather this year is not the same as the weather last year or next year. Annual mean temperatures and rates of precipitation tend to vary, as well as variability between years; there is a suggestion that mean values may be shifting over time (Intergovernmental Panel on Climate Change (IPCC), 1994).

Water deficit during pollination and grain formation may cause severe losses in crop productivity. During the reproductive stages of grain - crop growth, fully developed leaf canopies and high temperatures result in rapid water consumption so that stress due to water limitation can occur even if precipitation is lacking for just a short time.

Climate variability may manifest itself in changes in rainfall pattern. Extreme rainfall intensities may result in serious soil erosion and overall land degradation. It is also believed that prolonged drought conditions will adversely affect an entire hydrological regime of a region which may result in desertification.

The impact of climate variation on crop yield has recently gained prominence, given the significant trend towards global warming and impending climate change. Different aspects of climate variation such as higher CO_2 concentration, increased temperature and changing rainfall patterns all have significant effects on crop production and crop yield. These effects can either increase or decrease plant production depending on the interaction between these climatic factors.

It is well established that plants are highly sensitive to changes in climate- from hours of sun to rainfall and the application of water; soil conditions and particularly to temperatures due to effects on evapotranspiration. Drought conditions are often associated with high temperatures and intense heat. Physiologically, high temperature induce high rate of growth but the overall growing period becomes shorter. The shortened reproductive stage due to high temperatures limits carbohydrate accumulation resulting in overall yield reduction.

1.2 RATIONALE OF STUDY

Farmers in Ghana mainly depend on rainfall for their cropping activities. This is anchored on the existence of two distinct seasons – rainy and dry seasons; hence cropping is skewed towards the rainy season when the high amount of rainfall is believed to be adequate to supply crop water needs.

Agricultural productivity has been found to be affected by climate variability/change and since such changes cause response in many human and natural systems, understanding climate variability will improve agricultural decision making and eventually productivity. Climate variability/change has the possibility of degrading soil and water resources and subsequently subsistence agriculture production which is largely practised by maize farmers in the district.

The agricultural sector in the Ejura Sekyedumase District dominates all the other sectors of the economy in terms of employment. It employs about 68.2% of the population which is above the national average of 60% (Ejura Sekyedumase District Medium Term Development Plan 2006-2009)

The Ejura Sekyedumase District has the largest cropped area for maize (of 14,945-16,139 ha) compared to other districts in the Ashanti Region and has an average out put per year of 25,407 tons thus contributing to National food security.

The Ejura Farms Ltd. is a commercial farm established as a Limited Liability Company in 1969 by an American Merchant with the following share holders: Prospect Cooperation holding 51%, Ghana Government holding 20%, National Investment Bank holding 20% and Tannest International 9%. In 1976, Prospect Cooperation sold its share to the Government of Ghana and in 1978 National Investment Bank also sold its share to the Ghana Government. Currently the Ghana Government holds 91% shares with Tannest International which holds the managerial position having 9%. The Ejura farm is mainly engaged in the production of maize, cashew and rearing of cattle. The maize farm is located in Ejura (Ebuom). It has about 526.10ha of land under cultivation with an output of 3.71t/ha.

The farm produces to feed the town, the district, the region and the nation as a whole. Its contribution to GDP, food supply and income over the years cannot be overemphasized. It absorbs majority of the unemployed thereby reducing the unemployment rate in the district.

Rainfed maize production is one of the most important agricultural activities for majority of subsistence farmers in Ghana. The choice of the planting times to meet crop water requirement is a major problem for farmers. Wrong decisions could lead to reduced yield or total crop failure. Farmers are often compelled to react quickly to any change in onset of rainfall if targets for the planting are to be achieved. Effective use of this advantage of the bi-modal rainfall pattern could greatly improve production output of maize in the district. Water deficit during certain critical growth stages of the crop can cause severe losses in crop productivity.

Farmers expect their crops to give a good yield during a rainy season. Dry spells within average rainy season leads to reduction in crop yield. The severity of these dry spells sometimes leads to total crop yield failure. Clear understanding of these dry spells may lead to improved crop yield by putting in place measures to make available water for the crop.

The pattern and amount of rainfall are among the most important factors that affect agricultural production. Rainfall is the limiting factor in areas where there is rainfed agriculture; it governs the crop yields and determines the choice of crops that can be grown. Therefore, a detailed knowledge of rainfall pattern is an important pre-requisite for agricultural planning.

1.3 RESEARCH OBJECTIVES

Recently the impact of climate variability on crop yield has gained prominence, given the significant trend towards global warming and impending climate change. The level of perception of farmers in the district will determine the type of strategy package to adopt.

Adaptation has the potential to significantly contribute to reductions in negative impacts from changes in climatic conditions as well as other changing socioeconomic conditions. A better understanding of farmer perceptions regarding long-term climatic changes, current adaptation measures will be important to inform policy for future successful adaptation of the agricultural sector.

The study determined the trend of only rainfall and temperature as climatic variability indicators from 1993-2006 due to inability to have access to data on the other climate indicators such as humidity, duration of sunshine wind speed etc. The ability of farmers in the Ejura Sekyedumase District to detect climate variability/changes and their current adaptation measures was also assessed.

Specifically, the study will:

- Analyze precipitation and temperature as climate indicators for the past decade in the District.
- Assess the impact of past climate change on maize yields within the district
- Assess the perception of farmers on climate change/variability
- Find options that farmers' might have for adapting their cropping system to the climate variability and their perceived barriers to adaptation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Climate/Weather

Climate is the composite of all the many varied, day-to-day weather conditions in a region over a considerable time (Buckle, 1996). This time period should ideally be long enough (over 35 years) to establish relevant statistical information necessary to describe the variations in a region's weather (Buckle, 1996; Schulze *et al.*, 1997).

Schulze *et al.* (1997) described climate as more than average weather for it includes the dynamic and intricate variations occurring diurnally, daily, monthly, seasonally and annually and also includes evaluations of extreme events and the variability about the mean. According to Holden and Brereton (2004), climate also includes concepts of probabilities of occurrence of specific events (e.g. frosts, specific winds etc).

2.2 Climate and crops

Knowledge of climatology is an invaluable aid in the agricultural development and planning of a region. Climate and weather are key factors in agricultural production (Jones and Thornton, 2003). In some cases, it has been stated that as much as 80% of the variability of agricultural production is due to the variability in weather conditions, especially for rain fed production systems (Hoogenboom, 2000). Climate is one of the most important limiting factors for agricultural production: frost risk during the growing period and low and irregular precipitation with high risks of drought during the growing period, are common problems in agriculture (Moonen *et al.,* 2002). The critical agrometeorological variables associated with agricultural production are precipitation, air temperature and solar radiation (Hoogenboom, 2000). Because of the influence of temperature, precipitation, frost-free days, and growing degree-days on crop growth, long-term data on climatic variables are needed to predict which crops might be suitable (Young *et al.*, 2000). For example, they influence what crops can be grown in a region, the annual variation in crop and pasture production, and the amount of water available for livestock. Interrelations between climatic factors and crop characteristics are an important part of agro-climatological zoning.

2.2.1 Temperature

Most plant processes related to growth and yield are highly temperature dependent. Crop species may be classified as either warm or cool season types. The optimum growth temperature frequently corresponds to the optimum temperature for photosynthesis. Temperature increases can have both positive and negative effects on crop yields. Higher temperature also affects the rate of plant development (vegetative growth) and hence speeds annual crops through the developmental process, Bullock *et al.* (1995).

In general, temperature determines the rate of growth and development; but in some crops temperature may also determine whether a particular developmental process will begin or not (e.g. chilling requirement for initiating flower buds in Pyrethrum), the time when it will begin, subsequent rate of development and the time when the process stops. It is not temperature alone that is sufficient but precipitation must also be taken into account since the magnitude and seasonal variation of either or both can limit the growth and development of crops (ICRISAT, 1980).

The temperature regime is a key factor in maize adaptation and the use of the accumulated heat units (growing degree days) is of great importance (ICRISAT, 1980). Temperature increases, however, have also been found to reduce the yields and quality of many crops, particularly cereal and feed grains. For example, higher temperatures shorten the life cycle of grain crops, resulting in a shorter grain filling period, so the plants produce smaller and lighter grains, culminating in lower crop yields and perhaps poorer grain quality, i.e. lower protein levels (Wolfe, 1995). This is because temperature increases are associated with higher respiration rates, shorter periods of seed formation and consequently lower biomass production.

In the warmer lower latitude regions, increased temperatures may accelerate the rate at which plants release carbon dioxide in the process of respiration, resulting in less than optimal conditions for net growth. When temperatures exceed the optimum for biological processes, crops often respond negatively with a steep drop in net growth and yield. The accompanying accelerated physiological development may result in hastened maturation and reduced yield. Rosenzweig *et al.* (1993)

In addition, Rosenzweig *et al.* (1993) found evidence for important threshold effects. Their findings indicate positive crop yield responses to temperature increases of 2°C but yield reductions are observed at a 4°C increase. They also assert that crop impacts in lower latitudes tend to be more negative than crop impacts in higher latitudes, particularly with respect to wheat and maize yields. Rice yields are less variable than wheat and maize yield impacts. In addition, temperature changes can affect crop productivity. Higher temperatures may increase plant carboxilation and stimulate higher photosynthesis, respiration, and transpiration rates. Meanwhile, flowering may also be partially triggered by higher temperatures, while low temperatures may reduce energy use and increased sugar storage.

Reddy *et al.* (2002) concluded that the rates of plant growth and development would continue to increase in the southern U.S. because of enhanced metabolic rates at higher temperatures, combined with increased carbon availability. Combined changes in radiation and temperatures can produce various effects. For example, an increase in aerosols can typically reduce surface radiation levels, and hence, surface temperatures. If these aerosols are carbon-dominated, they can cause warming, while sulfate aerosols can cause further cooling.

2.2.2 Precipitation

Precipitation does not directly control any of the plant processes. It is considered to be a modifier that indirectly affects many of the plant growth and developmental processes. In the agro-climatological evaluation of rainfall, the most important considerations are the stability of agricultural water resources, the water requirements of agricultural plants and the identification and prediction of various agriculturally significant rainfall characteristics. Drought occurs during periods of insufficient rainfall, while water-logging occurs during periods of extensive rainfall (Hoogenboom, 2000).

Agronomists and soil scientists are interested in precipitation and rainfall in particular as a source of soil moisture to crops. Water supply is usually the most critical factor determining yield. The effects of water shortages on production may vary according to the particular crop, the soil characteristics, the root system, and the severity and timing of shortages during the growth cycle (Ahn, 1993). Reliability of rainfall, particularly at critical phases of plant development, accounts for much of the variation in agriculture's potential. Inter-annual or inter-seasonal rainfall variability is a major challenge to rain-dependent agricultural producers. In tropical agriculture, the high dependence on rainfall, coupled with low input use and degraded soils increases farmers' vulnerability to the vagaries of weather.

Climate change will also modify evaporation, runoff and soil moisture storage (Feddema and Freire, 2001; Nicholson, 2001). The occurrence of moisture stress during flowering, pollination and grain filling is harmful to crops, particularly to maize, soybean and wheat. The demand for water for irrigation is projected to rise in a warmer climate, leading to increased competition between agricultural and non-agricultural uses for water, falling water tables, and peak irrigation demands. Increases in precipitation may benefit semi-arid and other water shortage areas by increasing soil moisture, but could aggravate problems in regions with excess water, while reduction in precipitation could have the opposite effect (Ahn, 1993).

Feddema and Freire (2001) further affirm that global warming will affect regional water sources and have a significant impact on river flow regimes. They further observe that reduced water holding capacity may result in increased water runoff during the wet season. Water lost to runoff may increase deficits during rainy seasons, thus causing crops to suffer higher water stress during the dry season. Intensified evaporation may further increase the hazard of salt accumulation in the soil. This may disrupt growing conditions and result in crop failures, with serious implications for food security. Under such conditions, agricultural productivity could be severely limited. Investment in dams, reservoirs, wells and pumps may be needed to develop irrigation networks in new locations.

It has been shown that other factors such as humidity and wind speed combine to influence crop water needs. Crop water needs are higher when it is dry than when it is humid, and crops grown in windy climates use more water than those in calm climates. In most parts of sub-Saharan Africa, agricultural production is currently constrained by reduced soil moisture, e.g. in the West African Sahel and parts of southern Africa. Because water availability limits plant growth, further drying would reduce plant productivity (Schlesinger, 1990). The mean soil moisture (relative to soil water holding capacity) of the continent in the 1980s was about 9% lower than the average at the beginning of the century.

Soil moisture in northern and southern Africa has decreased by about 12% since the 1960s, indicating that climate change may have reduced the availability of soil moisture in Africa (Cao *et al.,* 2001). Soil warming may further cause decline in net primary productivity (NPP) as warming encourages microbial activity and can thus cause declines in the carbon stocks in soils (Oechel *et al.,* 1993).

Drought can cause an increase or decrease in developmental rates, depending on the stage of development. In many cases, the response to drought stress is also a function of species or cultivar, as some species or cultivars are more drought-tolerant than others. Drought can also reduce gross carbon assimilation through stomatal closure, causing a modification of biomass partitioning to the different plant components (Hoogenboom, 2000). Water-logging stress is caused by flooding or intense rainfall events causing a lack of oxygen in the rooting zone, which is required for root growth and respiration. A decrease in oxygen content in the soil can result in a decrease in root activities, causing increase in root senescence and root death rates. The overall effect of water- logging is a reduction in water uptake; the ultimate impact is similar to the drought stress effects (Hoogenboom, 2000).

2.2.2.1 Analysis of rainy season

The study of precipitation in any region is important from the view of agricultural production, drainage of urban and agricultural lands, erosion, flood, drought, water resources and civilization (Dinpashoh *et al.,* 2004). Rainfall, whether it is annual, seasonal or daily, is the most changeable of the weather elements varying in distribution, duration and intensity (Buckle, 1996). Understanding seasonal rainfall distribution is important for its influence on the economic activities of the population of Africa since agriculture is entirely dependant on rainfall and the economy of most African countries are driven by agricultural products (Buckle, 1996). The length of the rainy season including the time it starts and the time it ends are important

The analysis and prediction of the onset and the cessation dates of the rainy season is a key issue in the tropical countries which rely on rainy-fed agriculture (Pierre and Mbaye, 2003). On the whole, the growing season correspond to the rainy season, whose length differs from one year to the next and one region to the other. The strong dependence of crops on climate makes final prediction output highly variable as rainfall amounts, the onset, and cessation of the rains are subject to marked space-time variability (Pierre and Mbaye, 2003).

For West Africa, Dodd and Jollife (2001) considered the onset to be the first period of five consecutive days in which at least 25mm of rainfalls, on condition that no dry period (7 days or more) occurs in the following thirty (30) days. Omotosho *et al* (2000) also proposed that the onset is the beginning of the first two (2) rains totaling 20mm or more within seven days, followed by two to three weeks each with at least 50% of the local crop water requirement.

Samba (2001) in Niamey, defined it as the first occurrence of 10mm moisture content in the first 15mm of the soil was considered as the start of the cropping season provided that the crop water requirement are satisfied at 50% or more than twenty days afterwards.

In a study by Everline and Frederick (2001), they realized that the monitoring station which lies in the transitional zone had the first season starting during the last half of March but highly variable. The variability in the start and end of the rains was quite high as evidenced by standard deviation of greater than two weeks, this result in shorter crop growing period for maize growing in the bimodal and transitional areas.

2.3 Agro-climatological Descriptions

2.3.1 Growing season

The growing season is the period of time each year during which perennial crops such as pastures and forages and annual crops on the whole can grow (Government of Alberta, 2003). The growing season is different for different species. It depends on water, temperature and radiation conditions (Hakanson and Boulion, 2001)

White *et al*. (2001) described the length of the growing period as the time available when water and temperature permit plant growth, based on estimates of available soil water. It is important to determine the growing season of an area or station so as to investigate whether it can match the optimum growing period of a particular crop.

Caldiz *et al*. (2001) used the temperature constraints for the identification of the potential growing seasons and length of growing period for potatoes in Argentina. The growing season or period is sometimes referred to as the rainy season. When rainfall is the main constraint for agricultural production, the rainy season can be considered as the growing season. The rainy season's start and its duration have been previously investigated for agricultural, botanical, and ecological purposes: to define the effective time to plant, to estimate the growing season's length, germination and seedling emergence. When using rainfall to define the growing season, a long dry spell after the start of the rains causes a "false start" (Veenendaal *et al.*, 1996).

2.3.2 Dry spells

Semi-arid regions are characterized by dry weather spells. Occasionally these reach exceptional proportions which seriously disadvantage farming activities and require special agricultural planning strategies and management decisions (De Jager *et al.*, 1998). Although the definition of a dry spell may vary, depending on the aims and methodology used in each study, it generally refers to number of days without appreciable precipitation. A crucial aspect in this is the definition of a significant rainfall threshold in the typification of a dry day. Lazaro (2001) employed a threshold of 1 mm, since rainfall less than this amount is usually evaporated off the surface.

2.3.3 Wet spells

The length of a wet spell is defined as the consecutive number of days with a significant rainfall. The minimum length of a wet spell is taken as one day (Herath and Ratnayake, 2004). Sharma (1996) defined a wet day as a day with rainfall of more than zero and the probability of occurrence of a wet day depends on the climatic system of a place or region. Wet spells are an inherent property of climate, and depending upon their durations and the rainfall associated with them, they can have distinct advantages as well as disadvantages (Mwangala, 2003). For instance, in agriculture, wet spells of relatively short duration, typically not exceeding 3 days with light to moderate rainfall, can be very conducive to crop growth. However, if the spells are long, crop damage can easily occur as a result of water- logging in the soil or even flooding (Mwangala, 2003).

2.3.4 Water stress

Soil water stress will occur if there is not a balance between the atmospheric demand for water and supply of water available in the soil. Soil water availability is determined by the interaction of four factors:

1. Amount of water present in the soil,
2. Characteristics of the soil profile,
3. Water requirements of the crop and
4. Demand for water by the atmosphere (Shaw and Newman, 1991; Hoogenboom, 2000).

Atmospheric demand is a function of the energy available (solar radiation), movement of water away from the evaporating surface (wind), dryness of the air (humidity), and air temperature or sensible heat level (Shaw and Newman, 1991). For crop water to be adequate, the available soil water must be more than sufficient to meet the atmospheric evaporative demand. On windy, hot, sunny days with low humidity, for instance, evaporation demand on a crop is high; and thus, a high amount of available soil water must be present if the crop is to avoid stress. Under cloudy skies, high humidity and cooler temperatures, on the other hand, atmospheric evaporative demand will be lower. Less water is needed to meet the demand, thus, plants can survive with lower amounts of available soil water (Shaw and Newman, 1991).

2.4 Maize

Maize has been cultivated in Ghana for several hundred years after being introduced in the late 16^{th} century. Today maize is Ghana's most important cereal crop. It is grown by vast majority of rural households in all parts of the Country except Sudan Savannah zone and the far north (Morris *et al.*, 1999). 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. Over time, the eroding profitability of many plantation crops (attributable mainly to increasing disease problems in cocoa, deforestation and natural resource degradation, and falling world commodity prices) served to strengthen interest in commercial food crops, including maize (Morris *et al.*, 1999).

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. 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 labor requirements, and exercise complete discretion over the disposal of the harvest

According to official statistics, the area annually planted to maize in Ghana currently averages about 650,000 ha (Morris *et al.*, 1999). Most of the maize grown in Ghana is cultivated in association with other crops, particularly in the coastal savannah and forest zones, so planting densities are generally low. Average grain yields of maize are correspondingly modest when expressed per unit land area, averaging less than 2 t/ha. Total annual maize production is currently estimated at just over 1 million tons. Both of the two key determinants of production (area planted and yield) have increased over the longer term, although the upward trends have been characterized by high year-to year variability typical of rainfed crops (Boateng *et al.*, 1990).

Maize is the most widely consumed staple food in Ghana. A nationwide survey carried out in 1990 revealed that 94% of all households had consumed maize during an arbitrarily selected two-week period (Morris *et al.*, 1999). An analysis based on 1987 data showed that maize and maize based foods accounted for 10.8% of household food expenditures by the poor, and 10.3% of food expenditures by all income groups. (Boateng *et al.*, 1990).

Maize in Ghana is consumed in a variety of forms. In the north, it is commonly eaten as a thick gruel, similar to the way that sorghum and millet are consumed. In the south, it is frequently used to prepare porridges and more solid dishes made from fermented or unfermented dough. Many of these foods require considerable time and skill to prepare, which explains why a significant proportion of all maize consumed in Ghana as human food is purchased from specialized food sellers as prepared food, rather than as grain. Prepared foods are particularly important in urban areas, but they are also important in rural areas. A survey conducted in 1987/88 showed that, depending on the month, between 62% and 86% of all households that produced maize for their own consumption needs also purchased some maize products (Alderman, 1992).

Maize in Ghana is extensively traded. Miracle (1966) estimated that in the mid-1960s, fully one-third of Ghana's maize crop was being marketed—at the time an unusually high proportion for a subsistence crop in sub-Saharan Africa. The proportion has increased over the years with the rise of commercial farming. Today, at least half of the national maize crop is believed to enter the market (GGDP 1991; Alderman, 1991). The extensive marketing of maize has important welfare implications because revenues from maize sales represent an important source of income for many households, even households that grow maize primarily to satisfy their own consumption requirements. Nationwide, maize accounts for 16.8% of the revenues from crop sales earned by poor households and 18.5% of revenues from crop sales earned by "hardcore poor households" (Boateng et al., 1990).

2.4.1 Temperature requirements

The rate of growth and development of crops from planting to maturity is dependent mainly upon temperature. Maize is a crop with a rapid growth rate that yields best under moderate to warm temperatures. Cool temperatures slow down the progress to maturity and high temperatures hasten maturity (Brown, 1997). Each plant and animal has its own specific optimum temperature for growth and a temperature range in which it thrives. Once temperatures outside this range are encountered, the animal or plant suffers and growth slows (GA, 2003). Temperature (soil and air) during the growing period is the single most important environmental factor controlling maize development.

2.4.1.1 Germination

Before germination, the seed absorbs water and swells. The ideal temperature requirement for germination is from 16°C to 32°C (Rouanet, 1987). According to Sprague and Dudley (1988), optimum germination and emergence occurs when temperatures reach 20 to 22°C. Germination proceeds faster at higher temperatures assuming that water is available. Germination will be slow in dry soil, but will speed up as soil water increases until saturation is reached. For germination, the lowest mean daily temperature is about 10°C (Doorenbos and Kassam, 1988).

Maize also requires the soil temperature at seed depth to be favourable for seedling growth. Minimum soil temperatures of 10 to 13°C are required for maize germination and seedling growth. Cooler temperatures alone are not likely to impose a stress on the seedling, but only delay its emergence. According to Shaw and Newman (1991), maize usually emerges in 8 to 10 days at an average temperature of 16 to 18°C, but it takes longer (18 to 20 days) at 10 to 13°C. If the soil is wet enough and at an average temperature of 21°C, emergence may occur in 5 to 6 days. Even frost and freezing temperatures should not cause a problem during pre-emergence (Shaw and Newman, 1991). But wet weather together with cold temperatures following planting will favour development and activity of some soil pathogens that can produce disease stress in the young seedling (Shaw and Newman, 1991).

2.4.1.2 Early vegetative growth

Young maize plants are relatively resistant to cold weather (Lacey and Roe, 2001). From emergence to stage V6 (when six leaves have fully emerged), the growing point is below the soil surface and therefore recovery from moderate freeze is rapid and almost complete according to Ritchie *et al*. (1986). But later on, low temperatures will kill the plants whose growing point is at or above the soil surface (V8 stage or later). Air temperatures during the early vegetative stages should be around 25 to 35°C, which is considered optimum for rapid leaf growth (Sprague and Dudley, 1988). Growth during the early vegetative stage has been related to soil temperatures. Dry matter production in maize plants is greatest when average daily soil temperature at the 10cm depth is about 27°C (Shaw and Newman, 1991).

2.4.1.3 Late vegetative growth

Relationships between weather and yield are more significant in the late vegetative growth stages i.e., the 3 to 4 week period up to silking (Shaw and Newman, 1991). Temperatures of around 24°C during late vegetative stage result in yields near normal. The optimum temperature for this period ranges from 21°C to 33°C. If temperatures above 33°C are experienced, water stress may also occur. Under this dual soil water-temperature stress condition, vegetative growth will be reduced (Shaw and Newman, 1991).

2.4.1.4 Tasselling, silking and pollination

This is the most critical stage in maize development for any type of stress to occur. Combined soil water-temperature stress during the reproductive period can substantially reduce final grain yield (Shaw and Newman, 1991). Although separating the effects of these two stresses is difficult, most temperature stress conditions occur on high atmospheric-water-demand days i.e., days when the daily mean temperature is above 25°C and the daily maximum is above 35°C, regardless of soil water conditions (Lacey and Roe, 2001). Shaw and Newman reported that the 115-day cultivar took 74 days from planting to tasseling with an average temperature of 20°C, but only 54 days with an average temperature near 23°C and thus, the higher the temperature the shorter the phenological period. Cool nights reduce the rate of growth before tasseling (Lacey and Roe, 2001).

2.4.1.5 Grain-filling to maturity

For this period, the optimum minimum temperatures range is from 6°C to 21°C and the maximum temperatures from 18°C to 33°C. As seen from the wider range in this period, it is apparent that temperature has less influence on development and growth than in the previous stages. It has been well established that the longer the grain filling period the higher the grain yields provided frost does not kill the plant before the kernels are filled. Thus cool temperatures help to prolong the sub-periods of development and boost yields (Lacey and Roe, 2001).

2.4.2 Water requirements

Production of any agricultural crop is dependent upon an available supply of water during the growing season (Du Plessis. 2003). Each crop has a characteristic water use pattern throughout the season which is largely determined by the stages of the development of the plant.

According to Du Plessis (2003), maize can be grown in areas where the annual precipitation ranges from 250mm to over 5000mm. But Nield and Newman (1990) reported that, under dry land farming, maize is generally not grown in areas receiving less than 600mm of annual precipitation. Stone *et al.* (1996) reports the maximum crop water use for maize as being around 600mm. According to studies by Du Plessis (2003) in South Africa, maize needs 450 to 600 mm of water per season.

Water stress occurring during different development stages of maize may reduce final grain yield to different degrees, and the extent of yield reduction depends not only on the severity of the stress, but also on the stage of the plant development (Cakir, 2004).

2.4.3.1 Before planting

The influence of weather on the maize plant starts even before planting. Conditions before planting are especially important in determining the soil water reserves (Neild and Newman, 1990). These can reflected from a carryover from the previous cropping season or can be from accumulations that may occur during fallow period (Neild and Newman, 1990).

2.4.3.2 Planting to emergence

Maize seed placed in a wet soil at the right temperatures starts to swell by absorbing water (Rouanet, 1987). Adequate rainfall or water is very important during germination. Rainfall of 25mm should normally ensure that there is sufficient water in the soil to commence planting. At this stage, the water requirements of the crop are minimal due to low rate of evapotranspiration (Allen *et al.*, 1998). During emergence, while soil water must be adequate, excess water as well as cool conditions increases growth of fungi.

2.4.3.3 Early vegetative growth

Shortly after emergence, the maize plant shifts from dependence on food stored in the seed to that available in the soil and from photosynthesis (Shaw and Newman, 1991). The water requirement improves as the crop cover increases. Excess water in the early vegetative stages may severely injure the plants or retard early season root development as well as create aeration- nutrition problems (James *et al.*, 2007). In contrast, moderate water stress at these stages is advantageous, since such stress may encourage early-season root growth, which would prove beneficial later if soil water supplies become limited (Shaw and Newman, 1991).

2.4.3.4 Late vegetative growth

In the late vegetative stage, the maize plant grows rapidly and thus water requirements increases. At this stage higher evapotranspiration rate is experienced by the plant and transpiration from the crop contributes more than the evaporation from the soil surface since the crop cover is high (James *et al.*, 2007).

2.4.3.5 Tasseling, silking and pollination

As a maize plant grows, its demand for water increases with increasing leaf area which reaches a maximum near the tasseling stage (Neild and Newman, 1991). At this stage the water requirements are greater than other stages and thus severe water deficits may result in little or no grain yield due to silk drying (James *et al.*, 2007).

2.4.3.6 Grain filling to maturity

Hoogenboom (2000) reported that the water requirements for maize drop after the grain formation stage and gradually decreases as the crop matures and some leaves are senescing. Thus the LAI decreases gradually to harvest. At the physiological maturity, the grain must dry to a harvestable moisture level. Dry weather conditions are ideal for proper maturity and excess rainfall or wet day can severely deteriorate the yield quality.

2.5 Perceptions of Climate Variability

2.5.1. Cultural understandings of climate

Research on risk communication indicates that people filter and absorb climate information in terms of their prior assumptions and attitudes (Magistro and Roncoli, 2001, Morgan *et al.*, 2002). Thus, an inquiry into the cultural meaning that underlies farmers' understandings of climate, both its ordinary and abnormal manifestations, is a necessary first step in climate application studies. Given the centrality of 'seasons' in climate predictions, Orlove (2005) explored how different cultures divide the calendar year. Comparing data from 28 language groups, he examined terminologies used to name the seasons, their sub-components and their distinctive attributes and predictors. The analysis showed that most cultures divide the year into periods of different lengths, which are defined in terms of atmospheric and environmental observations.

2.5.2 Farmers response to climate predictions

Environmental change and economic globalization are exacerbating vulnerabilities for some areas and groups, while expanding opportunities for others (O'Brien and Leichenko, 2000). Resilience, defined as the capacity to buffer shocks and the flexibility to adapt to changed conditions, depends, among other things, on having 'timely, accurate, and credible information' (Kane and Yohe, 2000). Information management, including the processes whereby decision makers access information, ascertain the credibility of sources, combine various types of knowledge, and learn from their experience, is critical to adaptation (Yohe and Tol, 2002).

Climate predictions or forecasts relate to seasonal precipitation and other aspects of seasonal climate, such as temperature extremes (Goddard *et al.*, 2001). Climate prediction is one among many sources of information that can be used by decision makers to reduce risk and to optimize gains. Among sectors, agriculture stands to especially benefit from climate information because of the close link between climatic patterns and production outcomes (Hansen 2002). This potential has generated hope that seasonal rainfall forecasts may boost food security in highly vulnerable regions, such as Africa (Washington and Downing, 1999; Dilley, 2000). Yet research is still at an early stage as to how climate predictions can be transformed into tools for adaptive management. The way forecasts are likely to be understood depends on the way people think about climate variability, its causality and predictability and how they assess their vulnerability to climate risk, the options and trade-offs they face, and the potential consequences of decisions (Kates, 2000; Glantz, 2001).

2.5.3 Local forecasting knowledge

Local predictions provide clues about those aspects of climate that are most salient for farmers and about the kinds of climate information farmers seek to mitigate climate risk. At the same time, they can help enhance the relevance of scientific forecasts by integrating them with locally-specific observations. Ethnographic and participatory methods have been deployed to identify local sources and indicators for climate predictions used by farmers. Such methods include open-ended interviews and focus groups with farmers, elders, and local experts, as well as formal surveys to determine the distribution of knowledge in the general population (Roncoli *et al.*, 2002a, Luseno *et al.*, 2003).

These tools have elicited a rich repertoire of shared knowledge and specialized expertise based on environmental observations and ritual practices. In some cases, however, more effort has been directed to compiling inventories of signs and beliefs than to gaining insight into the cultural meanings and social life that such knowledge is embedded in. For example, the quantity of leaves and fruits produced by certain local trees are among the most common indicators mentioned by African farmers (Phillips *et al.*, 2001).

However, based on in-depth interviews in rural communities of Burkina Faso, researchers show that farmers do not rely on generic observations of any tree of a species. Rather, farmers base their predictions on specific trees located near their farms or homes, which have been objects of sustained monitoring over a lifetime of farming decisions (Roncoli *et al.*, 2002a). Fieldwork among Andean farmers also found that forecast meanings are firmly grounded in locality, being considered valid only for the specific site where they are produced (Valdivia *et al.*, 2003).

Researchers have used ranking matrices to elicit farmers' views of the relative importance of different indicators in order to identify which information parameters are most salient to them (Phillips *et al.*, 2001; Luseno *et al.*, 2003). These rankings, however, should be interpreted in the context of the variability of microenvironments, seasonal climate, and crop outcomes. For example, farmers may rank as highest those indicators that were most noticeable in the recent past or information about aspects of climate that have just occurred (e.g. end of the season) or that have had a particularly severe effect on crops (e.g. occurrence of dry spells). Significance of different forecast parameters also varies for different crops or activities (Ingram *et al.*, 2002; Ziervogel and Calder, 2003).

Given the diversified nature of rural livelihoods, farmers' knowledge sources and needs are likely to encompass a mix of parameters which may be significant for different types of producers or production systems. Field research among African farmers shows that they do not generally rely on a single forecasting indicator. Rather they consider signs and clues that arise at various times and from multiple settings, without striving to fit them into one coherent scenario (Roncoli *et al.*, 2002a; Luseno *et al.*, 2003). In farming, they combine their own experience with agricultural extension advice. To predict the future, they rely on traditional diviners as well as prophesies derived from Christian and Islamic scriptures (Roncoli *et al.*, 2002a). This eclecticism is a reflection of both cultural frameworks and environmental processes.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out in the Ejura Sekyedumase District, which is located within longitudes 1°5W and 1°39'W and latitudes 7°9'N and 7°36'N. It has a land size of about 1,782sq.km and is the fifth largest District of Ashanti Region's 21 Districts. It constitutes about 7.3% of the region's total land area with about 1/3 of its area lying in the Afram Plains.

The district lies within the transitional zone of the semi-deciduous forest and the Guinea Savannah zones. Thus it experiences both the forest and savannah climatic conditions. The district is marked by the two rainfall patterns, the bi-modal pattern in the south and the uni-modal in the north. The annual rainfall varies between 1,200mm and 1,500mm. It is located in the Northern part of the Ashanti region and is bounded in the north by Atebubu and Nkoranza districts (both in the Brong Ahafo region), on the west by Offinso district, on the east by Sekyere East district and the south by Sekyere West and Afigya Sekyere district.

Ejura-Sekyedumase district currently has a population of 88,753 (Ghana Statistical Service, 2000). Between 1984 and 2000, the population increased from 60,997 to 88,753. The district serves as the immediate- tie between the north and the south so harbours most northern extracts that are in search of greener pastures. The district served as the major food basket during the 1983 famine and therefore attracted people from all walks of life (Ejura Sekyedumase District Medium Term Development Plan, 2006).

The landscape in the southern part of the district is made of valleys and peaks. Averagely, the valleys have a depth of about 135m whilst the highest peaks rise to about 315m above sea level. The highest point in the district is made up of a range of hills, found in the eastern part and passes through Ejura and Mampong, forming part of the Kintampo-Koforidua range. On the other hand, the northern part is undulating and fairly flat with heights ranging between 150-300m. The district is dissected and well-drained by a number of rivers, streams and their tributaries. The drainage is dendritic in nature and has a west-east and northwest-southeast directional flow. Major rivers include; Afram, Akobaa, Chirade, Bresua whilst minor ones include Aberewa, Yaya and Baba (Ejura Sekyedumase District Medium Term Development Plan, 2006).

The parent rock belongs to the Upper Voltaian Series with its main components being the sandstone, shale and mud stone-beds, shale intrusions and sand, and pebbly bed series. The soils formed from these rocks are light textured (Ejura Sekyedumase District Medium Term Development Plan, 2006). Soils in the district are Savannah Ochrosols consisting of sandy loam or clay. The soils are well drained, deep, light in colour, well aerated and rich in organic matter and plant nutrients as well as high water-retaining capacities. They are easy to till and especially suited for mechanized farming. The type of soils found in the Forest zones of the district belongs tothe Forest Ochrosol . These soil types tend to support the cultivation of food and cash crops (Ejura Sekyedumase District Medium Term Development Plan, 2006).

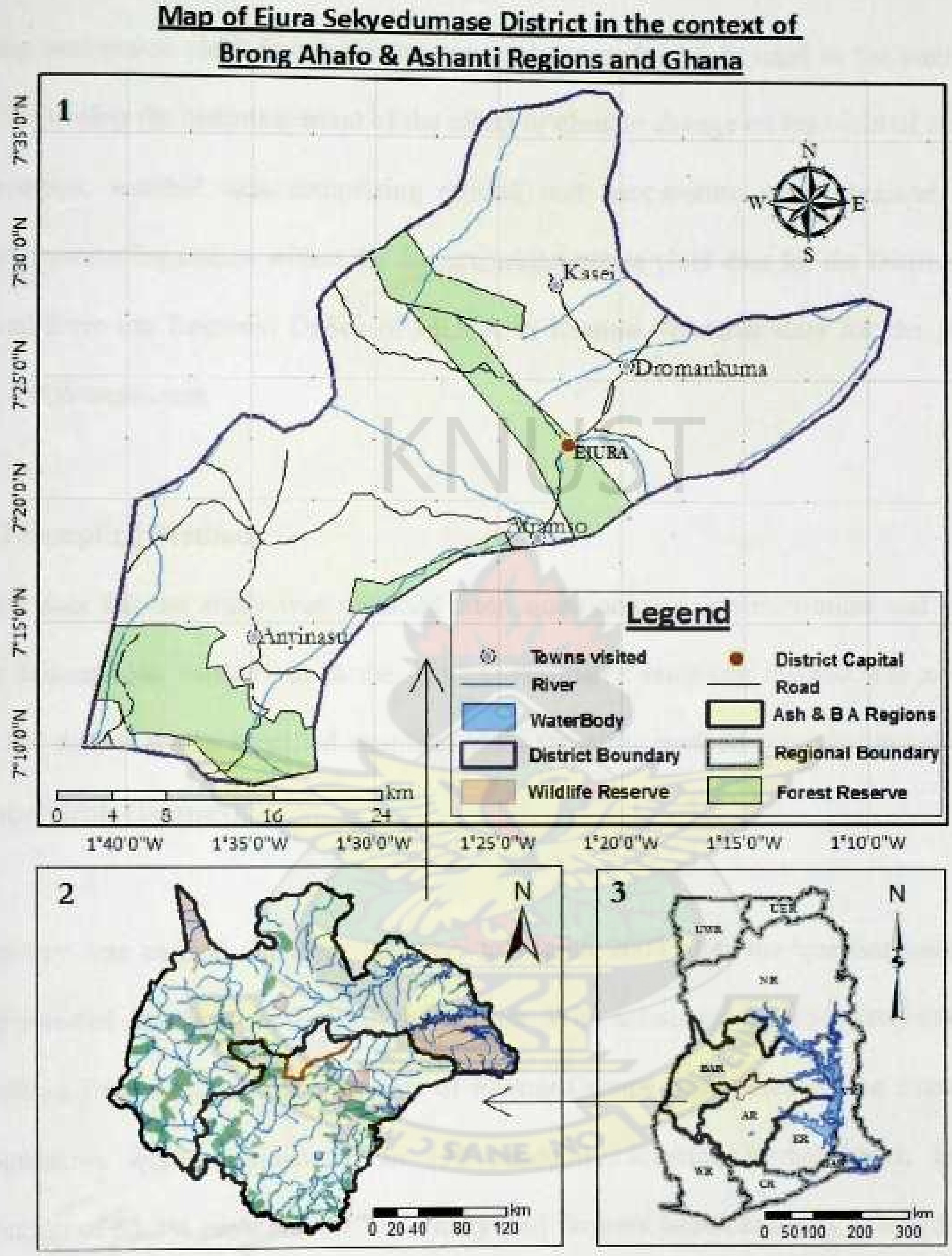

Fig. 1: Map of the Ejura Sekyedumase District in relation to Map of Brong Ahafo, Ashanti and Ghana

3.2.0 DATA COLLECTION

3.2.1.1 Source of Secondary data (climatic and yield data)

Climatic and maize yield data were the two main secondary data used in the study: In order to develop the historical trend of the effect of climate change on the yield of rainfed maize crops, weather data comprising rainfall and temperature were obtained from weather monitoring station within the district, whilst maize yield data for the District was obtained from the Regional Office of MOFA in Kumasi. Weather data for the period 1993 - 2006 were used.

3.2.1.2 Sampling Methods

Primary data for the study was obtained from questionnaire administration and Focus Group Discussions carried out in the district. Purposive sampling method was used to select the district whilst stratified simple random sampling method was used in selecting the respondents (farmers).

The survey was carried out from February to March 2007 after the questionnaire had been pre-tested at Babaso a village in the District. With assistance from Ministry of Food Agriculture Extension officers in charge of Farmer Groups in the district, the structured questionnaires were administered to 150 randomly selected farmers with gender distribution of 65.3% male and 34.7%. Thirty (30) farmers were randomly selected from each of the five enumeration areas (EA) which formed the sampling frame used by the Project Planning, Monitoring and Evaluation Division (PPMED) of the Ministry of Food and Agriculture in the district.

3.2.1.3 Focus Group Discussion

Two Focus group discussions were organized. The participants were recruited from the Office of the Ministry of Food and Agriculture (MOFA). For each group discussion, the participants that constituted the groups were five Field Extension Officers and a Senior Ministry staff from the MOFA office in Ejura Sekyedumase. The discussions were held on the premises of the MOFA office in the Ejura Sekyedumase District.

3.3 Data Analysis

3.3.1 Farmers perception on climate change

The data was analyzed using the Statistical Package for Social Sciences (SPSS). Descriptive analysis tools like Frequencies were used to determine proportion or correct relations within particular data collected, cross tabulation was used to look at relationship between variables.

3.3.2.1Rainfall data

The daily rainfall data were captured into Microsoft Excel 2007 spreadsheet following the days of year (DOY) entry format. Annual and monthly totals were calculated from the daily rainfall records sourced from the Ejura weather monitoring station. Microsoft Excel as well as INSTAT (Interactive Statistical Processing Package) and (Stern and Coe, 2002) was used to analyze daily records. The following event of rainfall as defined by Sivakumar (1988), were adopted, modified and used in this study.

- Start of the season: This is defined as the first occasion with more than 20 mm in 1 or 2 days after March and August 1st with no dry spell of length 7 days or more within the following 30 days.
- End of season: this was considered as the first occasion after June and October 1st that the water balance drops to zero.
- The length (duration) of the rainy season: this duration is defined as the number of rainy days from the start of the season to the end of the season.
- The seasonal total amount of rains at different phases and all year long is the total rainfall from start to end of rains.
- A linear regression model was used to identify the trends in rainfall y= $a + bx$
- Monthly coefficients of variability of precipitation $(CV) = \frac{SD}{MEAN} * 100$

3. 3.2.2 Temperature data

Monthly temperature data were analyzed using INSTAT statistical package as well as Microsoft Excel to look at the following:

- Frequencies at different thresholds
- Temperature at certain critical periods of the maize growth
- Coefficient of variability Temperature events $(CV) = \frac{SD}{MEAN} * 100$

3.3.3 Impact of recent climate variability/change on yield

A linear regression was ~~performed, with~~ intercept of the regression representing yield change per year with climate held constant to determine the relationship between difference (year - to - year changes) in yield and the climatic variables (Nicholls, 1997).

In this case, the climatic variables considered were the mean minimum and maximum temperature (Tmin and Tmax) and rainfall (Rain) during March –July and August – October the main months of maize growth and development.

CHAPTER FOUR

RESULTS

4.0 General observations and farm Characteristics from the field survey

The survey results showed that 65.3% of the farmers were males with 34.7% females, most of them within the age group 31-40 years (34.7%) and 41-50 (30.0%) (Table1). Eighty-four percent of the farmers had formal education with the least form of education being up to the Primary level. Sixteen percent of the farmers had no formal education.

Table 1: Age, Educational level and Gender Distribution of Farmers in the Ejura-Sekyedumase District

Criterion	Frequency	Percentage (%)
1. Age group		
20-30	15	10.0
31-40	52	34.7
41-50	45	30.0
Greater than 50	38	25.3
Total	**150**	**100.0**
2. Gender		
Male	98	65.3
Female	52	34.7
Total	**150**	**100.0**
3. Educational level		
Tertiary Level	10	6.7
Senior Secondary Level	8	5.3
Junior Secondary Level	71	47.3
Primary Level	37	24.7
No Formal Education	24	16.0
Total	**150**	**100.0**

Eighty-two point seven percent of the respondents were engaged in farming and allied activities as their main source of income, whilst 8.7% of the farmers made extra income from trading and other activities (Table 2).

Table 2: Major sources of income in the Ejura-Sekyedumase District

	Source of income			
Sex	**Farming**	**Trading**	**Other**	**Total**
Male	82(54.7%)	5(3.3%)	11(7.3%)	98(65.3%)
Female	42(28%)	8(5.3%)	2(1.3%)	52(34.7%)
Total`	**124(82.7%)**	**13(8.7%)**	**13(8.7%)**	**150(100%)**

All (100%) the respondents in the Ejura Sekyedumase District were engaged in maize cultivation. Aside cereals the next major food group produced is root and tuber crop (54%) (Table 3).

Table 3: Crops grown by farmers in the Ejura-Sekyedumase District

Crop	**Count**	**% cases**
Cereals	150	100.0
Root and tuber	81	54.0
Fruits and Vegetables	50	33.3
Cashew and Mango	1	0.7
Total Responses	**282**	**188.0***

* Percentages total more than 100 percent because more than one response from each person is included.

More than half (58%) of the farmers were natives of the District whilst 42% came from other districts. On the other hand, fifty-nine point three percent of the respondents in the District had been engaged in farming for more than 11years with only less than 5% of them having spent less than 4 years (Table 4).

Table 4: Nativity and farmers number of years in farming in the Ejura-Sekyedumase District

1. Native	Frequency	Percentage (%)
Yes	87	58
No	63	42
Total	**150**	**100**
2. Years spent in farming		
2-4	7	4.7
5-7	28	18.7
8-10	26	17.3
>11	89	59.3
Total	**150**	**100.0**

4.1 Farmers perception of climatic changes

Table 5: Farmers notice of variation in climatic conditions

	Farmers Response		
Years spent in farming	**Yes**	**No**	**Do not know**
2-5	6	-	1
5-8	23	2	3
8-11	22	2	2
>11	71	6	12
Total	**122**	**10**	**18**

The study revealed that 81.3% of the farmers had noticed variation in climatic condition and its effect on their farming practices over the years (Table 5).

Consequently, except for temperature changes which had been noticed by only 9 -14% of the farmers, over 75% had noticed changes in rainfall and drought (Table 6).

Table 6: Farmers' assessment of Climate

Perception of climate change by farmers	Count	%Cases
Change in rainfall pattern	149	23.3
Change in timing of rain appearance	135	21.2
Change in duration of drought	98	15.3
Reduction in amount of precipitation	107	16.7
Increased temperature	90	14.1
Temperature altered	60	9.4
Total	**639**	**100.0**

From Table 7, two main groups of responses were put forward as perceived causes of climatic variability by the farmers; they made reference to man made activities (38 %) and natural occurrence (32 %).

Table 7: Farmers perceived causes of Climate Change

Causes	Frequency	Percentage (%)
Deforestation	44	29.3
Natural occurrence	48	32.0
Bushfire	13	8.7
Do not know	45	30.0
Total	**150**	**100.0**

Table 8 shows farmers assessment of rainfall from the year 2005-2007 and it shows that rainfall events for the year 2005 varied significantly from the year 2006. Whilst a higher proportion of farmers (60%) believed there was a shortfall in precipitation for 2005, most of the farmers (72%) believed the precipitation in 2006 was good. In forecasting expected rainfall for the year 2007, more than half of the farmers (76.7%) could not predict, but only 23.3% did predict more rainfall (Table 8).

Table 8: Farmers' assessment of rainfall in the years 2005-2007

Farmers response	Frequency	Percentage (%)
Year 2005		
Excess rainfall	2	1.3
Good rains	57	38.0
Shortage of rain	90	60.0
Cannot recall	1	0.7
Total	**150**	**100.0**
Year 2006		
Excess rainfall	32	21.3
Good rains	108	72.0
Shortage of rain	6	4.0
Cannot recall	4	2.7
Total	**150**	**100.0**
Year 2007		
Excess rainfall	6	4.0
Good rains	29	19.3
Can't Predict	115	76.7
Total	**150**	**100.0**

4.2 Adaptation to climate variability in Ejura-Sekyedumase District

The type of information readily available to farmers in the District is information on agronomic practices (48.6%) and the least readily available information, is information on weather (19%). The sources of this information available to farmers in the district were Radio and TV (35.1%), from Agricultural Extension Officers (52%) and 12.9% from Fellow farmers in the district (Table 9).

Table 9: Farmers type and major source of information in Ejura Sekyedumase District

	Count	Percent Case (%)
Type of information		
Information on elements of the weather	48	19.0
Information on agronomic practices	123	48.6
Information on cultural practices	82	32.4
Total	**253**	**100.0**
Source of information		
Radio and TV	87	35.1
Agricultural Extension Officers	129	52.0
Fellow farmers	32	12.9
Total	**248**	**100.0**

Table 10: Maize planting periods by farmers in the Ejura Sekyedumase District during the major and minor season

Major season	Frequency	Percent (%)
March	7	4.7
April	40	26.7
March to April	47	31.3
April to May	57	37.3
Total	**150**	**100.0**
Minor season		
June - July	11	7.3
July	10	6.7
July- August	74	49.3
By looking up to other farmers	33	22.0
Wait until onset of rain	22	14.7
Total	**150**	**100.0**

The data in Table 10 indicates that, in the major season maize planting by farmers is not restricted to one month but spread from March to May, but most of the planting is done between April and May (37.3%). In the minor season, majority (49.3%) of the farmers plant their seeds between July and August, also quite a sizeable majority (22%) of the farmers plant their seeds by looking at other farmers (Table 10).

The farmers had different thoughts on the stage during the development of maize plant when water is considered critical; 2.7% of the farmers considered seed germination to be the critical stage, 4.7% of the farmers said it was both the seed germination and the tasseling stage, 3.3% said it was both tasseling and grain filling, although, most of the farmers considered tasseling (47.3%) and Grain filling (42.0%) to be the drought sensitive stage (Table 11).

Table 11: Stage water is considered critical in the development of maize by farmers in the Ejura Sekyedumase District

Stage of development	Frequency	Percent (%)
Seed germination	4	2.7
Seed germination and tasseling	7	4.7
Tasseling	71	47.3
Grain filling	63	42.0
Tasseling and grain filling	5	3.3
Total	**150**	**100.0**

Some adaptation measures being practiced by farmers in the Ejura Sekyedumase district to cope with climatic changes include; Soil water conservation (34.7%), move to non-farming activities (8.7%), Planting different varieties of maize (28.7%), Soil conservation (22.0%) and differing planting dates (6.0%) (Table 12).

With barriers to climate change adaptation, majority (42%) of farmers believe that lack of information is the major barrier to climate change, whilst a third (33.3%) of the farmers considered accessibility of water as the major barrier to climate change (Table 12).

Table 12: Farmers adaptation measures and major barriers to climate change adaptation in the Ejura Sekyedumase District

Adaptation measures	Frequency	Percentage (%)
Soil water conservation	52	34.7
Move to non-farming activities	13	8.7
Planting different varieties of maize	43	28.7
Soil conservation	33	22.0
Differing planting date	9	6.0
Total	**150**	**100.0**
Major barriers to climate change		
Lack of information about the weather	40	26.7
Lack of information about adaptation measures	23	15.3
Finance	37	24.7
Lack of water	50	33.3
Total	**150**	**100.0**

4.3.1 GROUP DISCUSSION

4.3.1.1 Knowledge of climate variability by Agricultural Extension officers

The Field Extension Officers had little knowledge in agro-meteorology. The Extension Officers received weather information from the media (Radio and TV) and sometimes from the Meteorological Services Department. Someof the Extension Officers were unable to "predict" expected weather condition for the coming season. However, a few were able to forecasts based on the state of the preceeding season with the notion that good and bad seasons alternate. That is, a previous bad season is an indication of an expected good one.

4.3.1.2 Traditional rainfall indicators used in the Ejura Sekyedumase District

Rainfall indicators used include plants, animals, insects, clouds and temperature. Some plants used to monitor seasons: include fruit trees like mango whose fruit set is used and the Indian almond which normally shed its leaves during dry season. According to the officers, mango trees usually flower and set fruits in February. A heavy fruit set is an indication of a poor coming season (April to July).

Certain seasonal sounds made by birds were believed to be communicating messages of changes in weather. The absence of frogs and toads indicates dry season and during the dry season frogs seldom croak. – When frogs stopped croaking during the rainy season even when it was still raining. It was also an indication of the stopping of rain. Some of them argue that termites carry food and store it just before heavy rains start, while others argued that ants would carry food and store before the onset of dry season

Some of them asserted that a good season is usually preceeded by a migratory flight of certain insects (termites). The ants' movements were considered a good indicator of wet/ rainy season approaching and when transporting food or their eggs is a clear indication of the closeness to a rainy season. However, there were controversies on the particular season the ants transport their food and eggs. Some asserted that for a good season, the first rainfall is usually heavy and is preceeded by a warm period while a poor season is preceded by cool periods in January to March and the first rains occur as showers.

4.3.1.3 Impact of weather forecast on crop production

On the impact of weather forecast information, a greater number of the officers believed that weather forecast information will result in a positive impact on agricultural production. Some of them were of the opinion that a forecast of bad season will result in a significant reduction in crop area by the farmers which then leads to total production decline.

4.4 Analysis of Seasonal Rainfall Pattern from 1993 – 2006

Analysis of the start of the two rainy seasons (Major and Minor) shows that start(S) of rain in March is common. The average start of rain was 22nd March (81 DOY). The average onset of rain during the major season for the period studied (1993-2006) was 8th April (SD 13 days) whilst the average minor season onset date was 31st August (SD 19 days) (Table 13).

The major season ends averagely on 10th July (192 DOY) with a standard deviation of eight days, whilst the minor rainy season ends averagely on 2nd November with eighteen days standard deviation (Table 13).

The length of the major rainy season varied from 183 to 209 days; with the average length of the major rainy season being 92 days with a standard deviation of 23 days. The minor season had an average length of 63 days with a standard deviation of 21 days. The coefficient of variability for the major season was 13% whilst that of the minor season was 33%.

Table 13: Start of rains, Onset of rains (DOY), End of rains (DOY) and Duration of rains (No. of Days) for the main rainy season in Ejura Sekyedumase District

	Major Season				Minor Season		
Year	Start	Onset	End	Length	Onset	End	Length
1993	68	97	190	93	248	309	61
1994	90	100	186	86	265	323	58
1995	77	99	209	110	249	312	63
1996	64	102	183	81	268	302	34
1997	86	106	184	78	244	275	31
1998	74	92	189	97	267	310	43
1999	63	105	191	86	234	300	66
2000	77	77	208	131	214	278	64
2001	89	89	198	109	253	304	51
2002	70	70	193	123	215	286	71
2003	89	89	187	98	255	335	80
2004	89	89	185	96	214	327	113
2005	72	110	186	76	242	323	81
2006	119	119	196	77	248	319	71
Maximum	**119**	**119**	**209**	**131**	**268**	**335**	**113**
Minimum	**63**	**70**	**183**	**76**	**214**	**275**	**31**
Range	**56**	**49**	**26**	**55**	**54**	**60**	**82**
Mean	**81**	**96**	**192**	**96**	**244**	**307**	**63**
SD	**15**	**13**	**8**	**17**	**19**	**18**	**21**
CV/%	**18**	**13**	**4**	**18**	**8**	**6**	**33**

Average Onset is 8th April (96 DOY) SD 13 days — 31st Aug (244 DOY) SD 19 days

End 10th July (192 DOY) SD 8 days — 2nd Nov (307 DOY) SD 18 days

Average length 92 days SD 23 days — 63 days SD 21 days

4.5. Temperature Analysis

4.5.1: Temperature at various growth stages

The analysis of the temperature between March and April (germination and emergence period during the major season) showed that 21.4% (3 years out of the 14 years) had the minimum temperature below the ideal minimum temperature of 16°C. The years which had their values below the ideal temperature were 1994, 2000 and 2001 and the ideal temperatures were found in the years 1993, 1995 -1999, and then 2000 to 2006. Thirteen years (92.9%) out of the 14 years had the maximum temperature above the ideal maximum temperature of 32°C. The ideal maximum temperature was recorded in the year 2000.

In the minor season, the temperature during germination and emergence stage (July-August) ranged from 15.2 to 23.1°C with four years (28.4%) out of the fourteen year having the minimum temperature below the ideal temperature of 16°C. The ideal temperature was recorded from 1996 to 2006 whilst the mean maximum temperature recorded for the period (1993-2006) had been within the ideal maximum temperature of 32°C (Table 14).

Table 14: Inter-annual temperature variation at germination and seed emergence stages

Season	OT (°C)	Tmin	Tmax	SDE	%T >OT
MAJOR					
Minimum temperature	16	15.2	23.1	2.58	21.4
Maximum temperature	32	31.5	36.0	1.35	92.9
MINOR					
Minimum temperature	16	14.6	23.3	3.82	42.8
Maximum temperature	32	28.5	31.8	1.01	0.0

OT: optimum temperature, T: observed temperature, SDE: standard error of mean, Tmin: minimum temperature, Tmax: maximum temperature

The results showed that the mean maximum temperature recorded in the months of May and June which coincides with maize tasseling, silking and pollination (critical period) stages in the major season ranged between 32.4 to 35.9°C. The period had 85.7% (12 years) out of the 14 years' temperature above the upper limit of the optimum temperature range (21°C-33°C) (Table 15). The ideal temperatures were recorded in the years 1993 and 1995.

For the minor season, the recorded mean maximum temperature ranged between 31.2 to 33.5°C during the tasselling, pollination and grain filling stages and had 21.43% (3 years) of the recorded values for the fourteen years being greater than the upper limit of the optimum temperature of 33°C by a difference of 0.5°C.

Table 15: Inter annual maximum temperature variation during the late vegetative and reproductive stages (Tasseling, Silking and Pollination)

		Temperature			
Season	**OT (°C)**	**Tmin**	**Tmax**	**SDE**	**%T >OT**
MAJOR	33	32.4	35.9	0.972	85.71
MINOR	33	31.2	33.5	0.608	21.43

OT: optimum temperature, T: temperature, SDE: standard, Tmin: minimum temperature, Tmax: maximum temperature

4.5.2: Inter annual variability of monthly temperatures

Table 16, shows the monthly mean minimum temperature from January to December with their coefficient of variability (CV). The CV ranges from 12.5% to 21.9%. The lowest coefficient of variability (CV) of 12.5% was recorded in March whilst the highest CV was recorded in July. The calculated CV for maximum temperature ranged from

1.9% to 5.4%. The highest coefficient of variability of 5.4% was obtained in December whilst the least value of 1.9% was obtained in October.

Table 16: Variability of monthly mean temperature (1993-2006) from Ejura Weather Monitoring Station

	Month											
Minimum temperature												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Maximum	21.1	22.8	22	23.1	23.1	22.1	23.5	23.3	24	24.8	23	23
Minimum	13.7	13.6	13.8	15.2	14.1	13.9	16.5	14.6	14.1	14	15.1	15.7
Mean	18.2	17.8	18.3	17.7	17.7	16.9	18.6	18.9	19.1	19.5	19	18.7
SD	3.04	2.7	2.4	2.6	2.7	2.6	4.1	3.9	3.6	3.5	3.1	2.8
CV/%	20.2	13.8	12.5	12.9	13.5	13.7	21.9	20.2	18.5	17.3	15.7	14.1
Maximum temperature												
Maximum	35.5	37.8	37.9	36.7	35.9	32.6	32.2	31.8	32.4	33.5	34.5	35
Minimum	32.5	35	30	31.5	32.4	29.5	29.9	28.5	30	31.2	27.7	28.2
Mean	34.2	36.4	35.3	34.6	33.9	31.4	30.9	30.1	31.3	32.5	32.9	33.2
SD	1	0.7	2.2	1.4	1	0.9	0.8	0.9	0.8	0.6	1.6	1.8
CV/%	3	2	6.2	3.9	2.9	2.8	2.7	3.1	2.6	1.9	5	5.4

4.5.3: Effects of Climate (Temperature and rainfall) variability on maize production

From studies done, different results have been obtained by different researchers depending on how climate has been and is expected to affect maize production in different parts of the world both at regional and local level situations.

A study by Jones and Thornton (2003) in Africa and Latin America showed both an increase and reduction in maize yield, with a reduction of about 10% in total production in both regions by 2055. This is ascribed principally to the expected increase in temperature and less conduciveness of rainfall for maize production. Another study done in 2002 in Africa showed a substantial spatial shift in maize cultivation in the region due to climate change by 2055. Specifically, the study results showed that under the assumed 2055 weather conditions, maize yield will be low in Zambia due to the expected increase in temperature and change in rainfall patterns.

This study assessed the role of rainfall in maize yield. The model result is presented in Table 17. It is evident that the variation in the independent variable (yield) is minimally (0.01%) explained by the variation in the dependent variable (annual rainfall). The model however does not significantly account for rainfall in explaining yield variations at the conventional 10% level. It also doesn't have a robust fit, being insignificant at the 10% level. Possible reasons are presented in the discussion section of Chapter 5.

Table 17: Effect of climatic conditions on maize yield variability in the Ejura Sekyedumase District

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.989313	6.292926	1.428479	0.1836
ANNRAI	-0.107007	0.090564	-1.18156	0.2647
RAINSQ	0.00036	0.000322	1.119109	0.2893

R-squared	0.171562	Mean dependent var	1.196331
Adjusted R-squared	0.005874	S.D. dependent var	0.448123
S.E. of regression	0.446804	Akaike info criterion	1.425783
Sum squared resid	1.996343	Schwarz criterion	1.556156
Log likelihood	-6.267589	F-statistic	1.035454
Durbin-Watson stat	0.8458	Prob(F-statistic)	0.390212

C is constant, ANNRAI is annual rainfall amount RAINSQ is the square of annual rainfall amount

CHAPTER FIVE

5.0 DISCUSSION

The purpose of this study was, in broad terms, to investigate how climate change (temperature and rainfall) had affected maize production in Ejura Sekyedumase District, and to find out which adaptation or mitigation strategies are being implemented.

The study on the farmer's perception revealed that most of the farmers in the Ejura Sekyedumase District were relatively young, active and were eager to learn innovations and also willing to learn to adapt their farming practices to changing climatic conditions (Table 1 and 2) and this result is similar to observations made by Banmeke and Olowu (2005) in Nigeria.

More importantly also the Socio-economic characteristics of individuals in a society has an influence in their adopting new agricultural practices according to Nnema and Adaeza, (2006) and Ja'Afar-Furo (2007). Thus, the 84% literacy in the farmers interviewed with agriculture being the main source of income is an indication that, they would be flexible towards change, hence introducing recommendations from findings in this study and appropriate adaptation measures for climate variability/change towards improving crop production in the district should not encounter many difficulties.

The relatively higher number of male farmers compared to females may be a reflection of certain traditional practices that does not allow women to own land and property as most of the farmers were of northern decent which is similar to observations made by Ja'Afar-Furo, in a study conducted in Northern Nigeria in 2007.

Information is one of the basic human needs after air, water, food and shelter and is needed to enable us manipulate factors of production such as Land, Labour and Capital resources into meaningful and productive use (Camble, 1992). Inadequate information therefore is one of the major causes of low adoption and production by farmers (Joshi *et al.*, 2005). Failure to implement adaptation options and poor agricultural performances by many African farmers has been blamed on lack of information and resources. New technologies or innovations are many a time useless unless it gets to the ultimate users safely (Ezike and Edze, 2004). Attempts made to find an effective route to channel findings of this study and modern methods of climate change adaptation measures to farmers in the study area through Agricultural Extension Officers and radio broadcast proved to be a major means of reaching out to the larger population of farmers in the district.

Climate models can paint a bigger picture of climate change and provide estimates for the likely consequences of different future scenarios of human development but in recent years, there has been an increasing realization that indigenous groups are valuable sources of information. The local people interpret and react to climate change impacts in creative ways, drawing on traditional knowledge as well as new technologies to find solutions, which may help society at large to cope with the current and impending changes.

De Wit and Stankiewicz (2006) make it clear that perception is a necessary pre-requisite for adaptation. In an attempt to look at the perception of the farmers on climate change in the district, the respondents' place of origin was considered. It was realized (Table 4) that most (52%) of the respondents were indigenes as against non-indigenes (48%), but both groups had lived in the district for periods long enough to notice changes in the climate variables being studied. This may explain why most of the farmers had noticed the changes in the climate vis á vis rainfall patterns and changes in temperature.

Agriculture is affected by both precipitation and temperature and hence, farmers who relied on rainfall for irrigation were most likely to notice these changes. According to all the farmers interviewed, rainfall had always varied in the area with wet and dry periods but they were of the view that these variations had increased in recent years: the rains start late and the amounts had also decreased. They also claimed that there were long periods of intense sunshine resulting in increased ambient temperature. Contrary, none of the farmers had noticed any reduction in temperature. It was also observed that, the more experienced the farmers, the more likely they were able to notice the changes in climate variables (temperature and rainfall) in the district.

Responses on the memory recall of the rainy season for the years 2005 and 2006 suggested a better season for 2005 as compared to the 2006 rainy season (Table 8). On comparing farmers' perception with the meteorological data of the area, the meteorological data supported farmers' assessment that the 2005 rainy season was better than the 2006 rainy season. This may be because, the start and onset of the rains for the

2005 season was a week earlier than the start and onset of the 2006, also the duration of the season was a month longer than the 2006 rainy season which could have had a significant effect on grain yield.

Majority of the farmers were aware of the effect of climate change on their activities, but had different thoughts on the causes. Most farmers attested to bush burning and deforestation being the main cause but also emphasized that these activities were their livelihood (Maurutto *et al.,* 2003). Because farmers are more vulnerable to the impacts of climate variability, it was presumed that they might have a greater understanding of this phenomenon. Yet, a sizeable minority (30%) of farmers admitted during the interview that they had very little knowledge of the causes of climate variability and called for more extension education. The study also revealed that it was difficult for the farmers to forecast on the expected rainfall and often based their forecasting on the previous year's rainfall pattern. This is an indication of the unpredictable nature of rainfall pattern in the district and confirms a statement made by Roncoli (2006) that "currently there is no available tool or model that can reliably predict duration and distribution of rainfall".

According to Jan and Anja (2007), people can draw on already existing mechanisms for coping with short-term adverse climatic conditions such as droughts or flooding. The results from the study showed that the respondents were not only keen observers of climate changes but were also actively trying to adapt to the changing climatic conditions. To cope with climate variability, the farmers have developed a wide range of adaptation measures; such as strategies to conserve soil moisture, move to non-farming activities, planting of different varieties of maize as well as changing planting dates (Table 12). Onset of rains is defined in relation to date of planting when rainfall has stabilized The choice of planting times to meet crop water requirement is a major problem to farmers (James *et al.,* 2007). Since farmers grow maize under\ rain-fed conditions, the start and stabilization of rains influence planting time and success of the crop. Planting dates actually vary from year to year according to the start and stabilization of rains.

Table 13 however shows, that over the 14-year period, farmers who take the risk of planting early may do so between day of year (DOY) 63 and 119 (2 March and 28 April), whereas the group of farmers who wait for the rains to be fully established will in the major season plant between DOY 70 and 119 (9 March and 28 April). The mean date for the rains to be fully established (onset) was 8th April with a 19 days standard deviation. The mean date for the rains to be fully established (onset) for the minor season was 31st August with standard deviation of 19 days. Thus planting before these mean dates carries with it the high risk of the seeds failing to germinate and the need for replanting which is very expensive if the seeds are to be purchased but will deplete farmers stock if they are in stock. The trend of start of rainy seasons, (Appendix 5, $R^2 = 0.18$) did show late start but correlation between the years and the start of rains was not strong and therefore could not strongly support farmers' perception of late start of the rains.

End of rains often determines the yield and quality of grains (Everline and Frederick, 2001). The end of rains (Table 13) for the major season ranged between 1st July to 27th

July (C.V 13%), and the minor season which range from 1st October to 30th November. This is an indication of high probability of cessation of rainfall before mean date of 10th July and 2nd November for the major and minor seasons respectively. Accordingly, the main growing season would not extend beyond the second week of July. This means that terminal drought can be climate variability stress condition on late planted maize crops or long maturity duration varieties.

The study carried out in the Ejura Sekyedumase district showed high variability in the start and end of the rains as evidenced by standard deviation of greater than two (2) weeks (Table 13). The start of the rainy season showed high variability with standard deviation of nineteen (19) days, whilst end of the season also showed wide variability (SD of 18days). Seasonal length can vary from 70 to 119 days for the major season whilst the minor seasonal length can vary from 32 to 113 days. Maize varieties currently being grown by farmers like Okomasa are 120-day cycle (Maize Production Guide, 2005). Strategic planting periods are needed to iron out yield losses caused by such fluctuations.

Fluctuations in the length of the growing season only permits full confidence of receiving rainfall in the peak periods between April-May and September-October for the major and minor seasons respectively. It was realized that, the seasonal length between the major and the minor was quite pronounced with the major season being considerably longer than the minor.

In the major season, the shortest expected season is when the season onset is late 24[th] April and breaks early 4[th] July giving a seasonal length of 76 days. In this situation planting during mid – March would utilize the pre- season rainfall for germination. The rains would get the crop at an advance stage. The most critical moisture requirement stage of Okomasa and current grown varieties is between 47 days after sowing to 69 days after sowing (Maize Production Guide, 2005; Everline and Frederick 2001). The crop would attain these between 2[nd] May and 30[th] of May leaving still 30 days for part of grain filling. From this, it is possible for farmers to still get some yield even during bad years. Everline and Frederick (2001) obtained similar results while defining growing season for sorghum. Results from the trend analysis for the length of the first growing season, March to July showed no significant decreasing trend ($R^2 = 0.17$, $p>0.5$), which could not support the farmers' perception of decreasing trend in length of rainfall season. The period when maize is sensitive to drought for the major season April and May, did not show any significant trend (Appendices 5 and 6).

The second growing season, August to October also showed an insignificant decreasing trend ($R^2 = 0.15$, $p>0.5$), and there was also no significant trend for the drought sensitive period (September and October). Mean annual precipitation recorded for the Ejura Sekyedumase district was 1223.6mm. Most of the rainfall received was from the months March to October, from November to February it falls as showers. The inter-annual variability of rainfall in the individual months of the seasons was high, and ranged from 26.8% to over 100% (Appendix 10).

The coefficients of variability for minimum temperature (Table 14) demonstrate an unmistakable contrast between minimum and the maximum temperature variations. In almost all the months, the minimum temperature coefficients values were higher than the maximum temperature coefficient of variability values. The coefficient values for February to June were below 20% so is October to December. The highest variability has been in July (21.91%) followed by August and January. The variability of maximum temperature as depicted in Table 16 was very low, averaging less than 5 percent from January to October but rise a little above 5% in November and December. The implication of this is that each year was very much like the other with respect to daytime temperatures. The results for the monthly mean maximum temperature values recorded exceeds the optimal temperature requirement for maize at the different developmental stages by 3°C (Table 14 and 15).

Apart from climatic factors, it was found that total production is dependent on different factors as mentioned by different interviewees (compare Table 12).

Though there are a lot of factors affecting production, climate affects production through its effects on yield. However, yield is also dependent on both climatic and non-climatic factors. As mentioned by Long *et al* (2005), it is determined by available light energy and genetic properties, and studies done by different researchers (Mati, 2002; Matarira et al, 1995; Jones and Thornton, 2003; and Jones and Thornton, 2002) indicate that there are a lot more factors that determine yield which include: temperature, precipitation, solar radiation, soil parameters (which include: particle size, moisture holding capacity, and bulk density), and crop management (which include: planting dates, fertilizer application and seeding rates).

This means that to quantify the effects of climate change on total production, all factors (both climatic and non-climatic) affecting productions have to be taken into consideration. An effort was made to run a multiple regression of yield against rainfall and temperature using SPSS, but the results did not show any significance that either rainfall or temperature have effects on maize yield though Table 17 showed annual precipitation explain more than 0.59%. However the sign of the marginal or yield response (Table 17) is quite contrary to intuitive explanation. Thus, initially 1mm increases in rainfall amount leads to 0.11t/ha decreases in yield. Further marginal rainfall increase after a point however leads to a 0.0004t/ha increase in yield. This doesn't sound well because the reality should have been the opposite for the two variables. This might be as a result of inadequate data set and its validity a direct relationship between total rainfall and total production.

However, though such results were obtained, not all data affecting maize production was included in the analysis. Some data for example, fertilizer application or type of seeds planted could not be obtained due to non-availability of such data from the interviewees and offices visited

5.1 CONCLUSION

Scientists have reported that climate has changed and will continue to change. However we do not know (yet) the extent of the future change and how it will affect different localities due to limited knowledge available. An effort was made to estimate the impact of temperature and rainfall on maize production. However, since it was impossible to isolate the impact of these variables from the impact of other variables, the results did not show with any significance that either temperature or rainfall has effect on maize production. Moreover, it is not easy to quantify the effects of climate change due to difficulties in quantifying other factors that may also have large impact on maize production. Thus, it was therefore, not possible to conclude whether or to what extent climate change has effects on maize production.

Based on results from this study, almost all the farmers and staff of MOFA in the Ejura Sekyedumase District believed that rainfall levels had decreased and that there had been a change in the timing of the rains and an increase in average temperatures. Some of the adaptation measures being used by the farmers include planting of different varieties of maize, soil moisture conservation, changing the planting dates and a move to non-farming activities.

Lack of credit or savings, lack of information about weather and information on adaptation measures and lack of access to water were the main factors inhibiting adaptation. Contrary to farmers' perception, the analyses of the meteorological data from the Ejura Weather Monitoring Station did not strongly support the farmers' claims.

5.2 RECOMMENDATION

In the minor season with short rainy period of 1- 3 months, early planting in July before the onset of rains at the end of August can allow the maize crop to capture the full length of all incidental rainfall. The focus here should be placed on selecting those varieties and agronomic practices that can enable the maize crop to germinate and establish on low soil moisture profile before the actual rainy season sets in.

Additionally, further studies could be carried out in the district to record traditional weather monitoring and prediction indicators to establish their reliability and scientific interpretation to harmonize them with the modern scientific methods.

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APPENDICES

Appendix 1: Questionnaire on Assessment of Maize Farmers Perception on Climate Variability and Change in the Ejura Sekyedumase District.

A. DEMONGRAPHIC AND SOCIO- ECONOMIC RECORDS

1. Name of Enumeration area.................................
2. Sex of respondent: Male [ ] Female [ ]
3. Age of respondent: 20-30yr [ ] 31- 40[ ] 41-50 [ ] Above 50 [ ]
4. What is the level of education :

No formal education [ ] Basic education [ ] JSS/MSLC [ ]

SSS/AL [ ] Tertiary [ ]

5. Are a native of this district : Yes [ ] No [ ]
6. How long have been in the district?

2-5yrs [ ] 5 – 8 [ ] 8- 11 [ ] 11yrs above [ ]

7. What is you main source of income...
8. Number of years in farming : 2-5yrs [ ] 5 – 8 [ ] 8- 11 [ ] 11yrs above [ ]
9. Type of farming: Mono cropping [ ] Mixed cropping [ ] Mixed farming [ ]
10. Type of crops grown: Cereal [ ] Root and tubers [ ] Vegetables [ ] Cash crops [ ]
11. What type of cereals do you produce: Maize [ ] Millet [ ] Sorghum [ ] Rice [ ]
12. If maize is the main cereal grown, how many varieties do you grow?.....................

B. FARMERS PERCEPTION ON CLIMATE VARIABILITY AND CHANGE

13. Have you notice any change in rainfall? Yes [ ] No [ ]
14. Can you describe the change in rainfall?

    A. ....

    B. ....

    C. ....

15. What do you think is the cause of the change in rainfall you mention above?

....

16. What period do you usually plant your crops?

    A. Major season..............................

B. Minor season..............................

17. Has there been a change in the farming calendar due to changes in rainfall?

Yes [ ] No [ ]

18. What change(s) can you mention...

19. Is there any improvement in yield as a result of the changes you mention above?

Yes [ ] No [ ]

20. What stage(s) of the maize growth period is water critical to the plant?

Seed germination [ ] tussling stage [ ] Grain filling [ ] other [ ]

21. Did you get rains during this period(s) for the past four seasons?: Yes [ ] No [ ] Sparingly [ ]

22. Do you receive information on expected precipitation and temperature from extension officers? Yes [ ] No [ ]

23. Have you notice any change in the ambient temperature? Yes [ ] No [ ]

24. What do you look for before planting your crops...

25. Do you receive any information that helps you in your farming activities?

Yes [ ] No [ ]

26. What type of information...

27. What is the source of the information...

C. ADAPTATION MEASURES BY FARMERS

28. What measures do think can help you in order to adapt to these changes in climate variables?

1. Water conservation techniques[ ]
2. Moved to non-farming [ ]
3. Planting of different varieties of the maize crop
4. Soil conservation practices [ ]

D. PERCIEVED BARRIERS TO ADAPTATION BY FARMERS

29. What do you consider to be a barrier for you to adapt to climate change?

1. Lack of information about the weather [ ]
2. Lack of information about climate change[ ]
3. Lack of knowledge about adaptation measures [ ]

4. Finance [ ]
5. Accessibility to water [ ]

E. FARMER ASSESSMENT OF RAINFALL 2002 - 2007

YEAR	Total amount of rainfall received	Distribution of rainfall
	1=excess rain 2=good rains 3=shortage of rain 4=can't recall 5= Can't predict	1=excellent 2=good 3=poor 4=can't recall 5= Can't predict
2006 **(last season)**		
2005		
2004		
2003		
2007 **(this season)**		

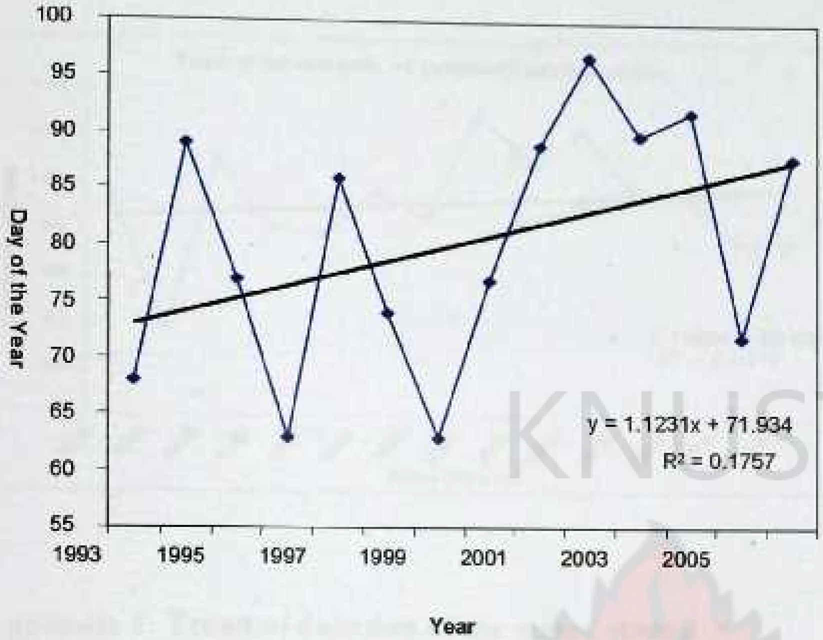
Appendix 2: Major season planting time by farmers in the Ejura Sekyedumase District

Enumeration area	Period of major season planting of maize				Total N
	March-April	April- May	March	April	%
Kasei-Aframso	9	12	1	8	30
	30.0%	40.0%	3.3%	26.7%	100.0%
Ashakoko-Dromankuma	6	12	2	10	30
	20.0%	40.0%	6.7%	33.3%	100.0%
District Admnistration -Bayere Nkwanta	8	11	1	10	30
	26.7%	36.7%	3.3%	33.3%	100.0%
Appia-Dwah / Hiawoanwu	9	20	0	1	30
	30.0%	66.7%	.0%	3.3%	100.0%
Anyinasuso	15	1	3	11	30
	50.0%	3.3%	10.0%	36.7%	100.0%
Total	47	56	7	40	150
	31.3%	37.3%	4.7%	26.7%	100.0%

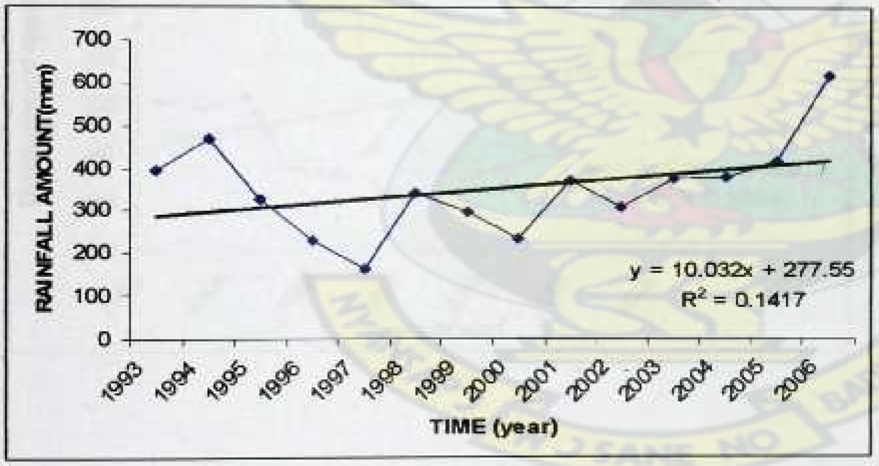
Appendix 3: Minor season planting time by farmers in the Ejura Sekyedumase District

Enumeration area	Period of minor season planting of maize					Total N
	July-august	Determine planting by looking at others	June-July	July	Wait till rain is fully established	%
Kasei-Aframso	12	1	11	5	1	30
	40.0%	3.3%	36.7%	16.7%	3.3%	100.0%
Ashakoko-Dromankuma	8	12	0	0	10	30
	26.7%	40.0%	.0%	.0%	33.3%	100.0%
District Admnistration - Bbayere Nkwanta	25	0	0	1	4	30
	83.3%	.0%	.0%	3.3%	13.3%	100.0%
Appia-Dwah/Hiawoanwu	10	19	0	1	0	30
	33.3%	63.3%	.0%	3.3%	.0%	100.0%
Anyinasuso	19	1	0	3	7	30
	63.3%	3.3%	.0%	10.0%	23.3%	100.0%
Total	74	33	11	10	22	150
	49.3%	22.0%	7.3%	6.7%	14.7%	100.0%

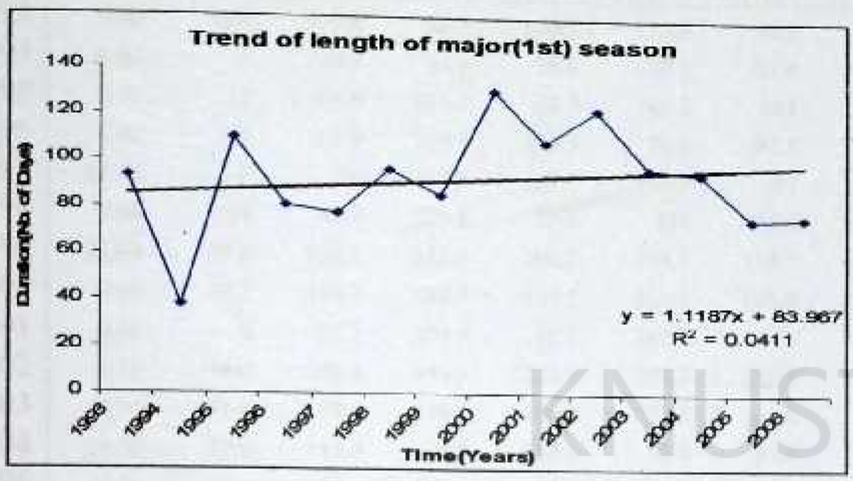
Appendix 4: Trend of season start(s) of rains for the period 1993-2006



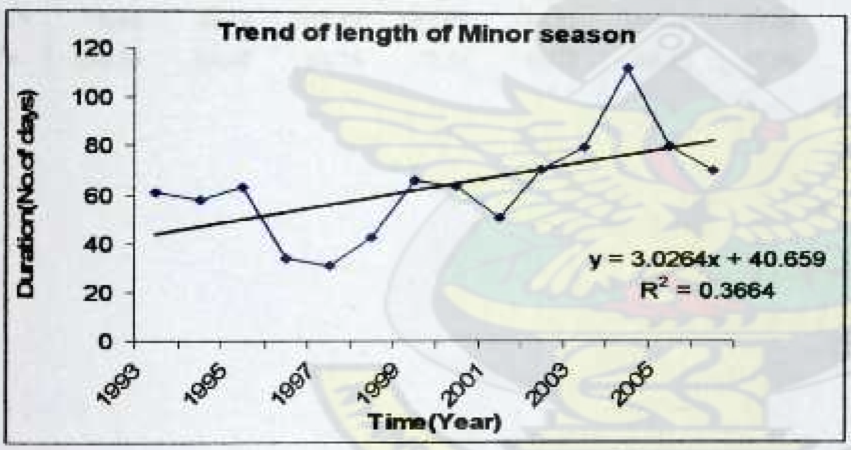
Appendix 5 Trend of rainfall amount at drought sensitive period in minor season



Appendix 6 Trend of duration of major season



Appendix 7: Trend of duration of the minor season



Appendix 8: Variability of monthly rainfall amount from1993-2006

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OC
1993	0.00	58.4	139.6	89.7	110.1	113.6	40.6	124.1	213.8	[illegible]
1994	0.00	0	110.3	86.6	96.9	119.9	31.4	25.4	112.8	[illegible]
1995	0.00	12	109.9	194.3	98.7	140.2	144	44.8	182	[illegible]
1996	0.00	67	64.8	102.5	195.3	76.9	97.4	35.2	118.8	[illegible]
1997	36.40	0	80	167.1	163.6	195.9	87	95.9	165	
1998	0.00	58	45.9	220.2	83.6	236	76.6	96.2	116	[illegible]
1999	15.90	55.8	212.1	253.6	101.1	164.1	150.5	122.9	140.3	
2000	0.00	78.7	148.3	148.3	130.7	235.2	127.6	178.4	160.2	
2001	0.00	0	63.3	194.5	88.1	142.4	70	18.3	250.1	
2002	4.70	16.4	80.4	146.3	222.9	227.5	158.8	124.5	192.9	
2003	4.30	161.8	58.8	154.3	100.3	273.3	36.6	27	229.5	
2004	24.30	47.6	115.9	125	280.6	68.8	91.4	251.4	198.1	
2005	0.70	70.4	134.8	204.5	133.4	94.8	46.5	98.9	234.3	
2006	35.20	47.8	66.4	54.8	283.7	148	99.3	8.7	251.9	
Max	36.40	161.80	212.10	253.60	283.70	273.30	158.80	251.40	251.90	3
Min	0.00	0.00	45.90	54.80	83.60	68.80	31.40	8.70	112.80	
SD	**13.57**	**43.17**	**45.74**	**57.09**	**69.76**	**64.58**	**43.03**	**69.27**	**49.24**	
MEAN	**8.68**	**48.14**	**102.18**	**152.98**	**149.21**	**159.76**	**89.84**	**89.41**	**183.27**	**1**
CV/%	**156.36**	**89.69**	**44.76**	**37.32**	**46.75**	**40.42**	**47.90**	**77.48**	**26.87**	

Appendix 9: Variability of monthly minimum temperature

Month	Tmean	Tmin	Tmax	SDE	%<16°C
JAN	15.51	10	21.1	3.136	57.14
FEB	17.69	13.6	22.8	2.441	21.43
MAR	18.32	13.8	22	2.296	7.143
APR	17.47	15.2	23.1	2.258	21.43
MAY	17.51	14.1	23.1	2.373	21.43
JUN	16.73	13.9	22.1	2.3	35.71
JUL	18.69	12.5	23.5	4.096	42.86
AUG	18.88	14.6	23.3	3.825	42.86
SEP	19.12	14.1	24	3.541	28.57
OCT	19.46	14	24.8	3.377	7.143
NOV	18.96	15.1	23	2.977	7.143
DEC	18.6	15.7	23	2.63	21.43

Appendix 10.Variability of monthly maximum temperature at various stages of maize growth and development

Month	Tmean	Tmin	Tmax	SDE	%>32°C	%>33°C	%>35°C
JAN	34.16	32.5	35.5	1.013	100	78.9	21.43
FEB	36.36	35	37.8	0.7186	100	100	92.86
MAR	35.33	30	37.9	2.181	85.71	85.71	64.29
APR	34.62	31.5	36.7	1.352	92.86	92.86	35.71
MAY	33.89	32.4	35.9	0.972	100	85.71	14.29
JUN	31.39	29.53	32.6	0.866	21.43	0	0
JUL	30.88	29.9	32.2	0.827	14.29	0	0
AUG	30.14	28.5	31.8	1.012	0	0	0
SEP	31.26	30	32.4	0.8139	14.29	0	0
OCT	32.52	31.2	33.5	0.6079	78.57	21.43	0
NOV	32.86	27.7	34.5	1.65	92.86	57.14	0
DEC	33.18	28.15	35	1.795	78.57	57.14	0