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Climate Change and Crop Production in the Mfantseman Area of Ghana

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ABSTRACT: The extent of climate change and its possible effect on crop yield in the Mfantseman area of Ghana was studied. Climatic data was obtained from the Ghana meteorological service, Saltpond. The data obtained were: daily rainfall, temperature, relative humidity and solar radiation recordings covering a period of 20 years. Crop yield data was also obtained from the office of Ministry of Food and Agriculture (MoFA) at Cape Coast. The data was analysed to determine variations in the following: annual rainfall, mean temperatures, date of onset of the rainy season and irrigation water requirement, and crop water requirement for maize. It was observed that the rainy season was seen to be starting later than previously; annual rainfall was seen to be decreasing but temperatures were seen to be increasing. It was also observed that crop water requirement for maize was declining steadily. There were fluctuations in crop yields but no clear trend emerged. Declining rainfall and increasing temperatures may be responsible for the decreasing yields.

Keywords: Climate change, rainfall, temperature, relative humidity and crop yield.

INTRODUCTION

Climate change refers to a secular trend that produces a long term significant change in the average climatic conditions (Berger, 1980) and variability is an inherent characteristic of climate and clearly related to the concept of climate change (Gibbs *et al.*, 1975). It is estimated that global warming due to doubling of carbon dioxide mean values caused by natural mechanisms or by human activity can raise global temperature by between 1.5 and 4.5^{o}C (Kelly and Hume, 1993). This is leading to rising sea levels, the disappearance of glaciers, drastic changes in rainfall patterns thereby affecting the production potential of rural areas (IPCC, 2008). Rising carbon dioxide levels would also have effects, both detrimental and beneficial, on crop yields. The overall effect of climate change on agriculture will depend on the balance of these effects.

According to Lobell *et al.* (2008) southern Africa could lose more than 30% of its main crop, maize, by 2030 due to climate change. In south Asia losses of many regional staples, such as rice, millet and maize due to climate change could top 10%. The poorest countries would be hardest hit, with reductions in crop yields in most tropical and sub tropical regions due to a decrease in water availability, and new or changed insect pest incidence (IPCC, 2007). In most African and Latin America countries many rain fed crops have reached their maximum tolerance, so that yields are likely to fall sharply for even small climate changes; falls in agriculture productivity of up to 30% over the 21st century are projected.

Climate change may increase the amount of arable land in high latitude region by reduction of the amount of frozen lands. Sea levels are expected to rise to one meter higher by 2100. Vietnam for example relies heavily on its southern tip, where the Mekong Delta lies, for rice planting. Any rise in sea level of no more than a meter will drown several square kilometers of rice paddies, rending Vietnam incapable of producing its main staple and export of rice (IRRI, 2007)

There is a lot of information on global warming and global climate change and their potential impact on the world. On agriculture, it is believed that crop yield is going to be adversely affected by climate change. However, little research has been done at the local level to know the extent to which climate change can affect crops. Assessment of the effects of climate changes on agriculture might help to properly anticipate and adapt farming to maximize agricultural production. This study attempts to assess the extent of change in climate over two decades and its potential impact on crop production in the Mfantseman area in the Central Region of Ghana.

MATERIALS AND METHODS

Study Area description

Mfantseman area lies around latitude 5 º North of the Equator and between longitudes 1 .11º to 1.41º West of the Greenwich Meridian. According to Asamoah (1973), temperatures range between 24ºC and 32ºC with relative humidity ranging between 70% and 90%. The district experiences a bimodal rainfall regime with the peak in May-June and October. The annual total rainfall ranges between 900 mm along the coast to between

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1100 mm and 1600 mm in the hinterland. Dry periods (harmattan) are experienced between November and February. Land is generally hilly and the highest point is approximately 60 m above sea level.

Crop Yield Data

The yield data available was for the following crops: maize, cassava, plantain and yam. It was for a period of ten (10) years from, 1998 to 2008 and obtained from Ministry of Food and Agriculture (MOFA).

Data Analysis

The data collected from the meteorological station were analyzed using simple descriptive statistics with graphs and trend lines.

Crop Water Requirement

CROPWAT 8.0, a computer program for the calculation of crop water requirement and irrigation water requirement based on soil, climate and crop data (FAO, 2010) was used for the determination of the crop water requirement. The test crop used was maize. Climatic data for the study area was used; however crop and soils data inherent in the application were also used.

Climatic Data

Climatic data was obtained from the meteorological services at Saltpond. The data collected were rainfall, temperature, relative humidity, evaporation and sunshine duration. Variations in sunshine were very minor and as such it is not presented. Variation in All the data collected covered a period of twenty years.

RESULTS AND DISCUSSION

This section presents the data obtained in graphs and shows the trend over the last 20 years

Annual Rainfall

Amongst other things, changes in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields. Rainfall amount and timing influences the yield of crops. Low rainfall amounts can be detrimental to crop yields, especially if dry periods occur during critical development stages. For example, moisture stress during the flowering, pollination, and grain-filling stages is especially harmful to maize, soybean, wheat and sorghum (Decker *et al*., 1985). Rainfall increase affects crop yield positively by readily dissolving the nutrients for easy soil absorption by plants (Rosenzweig and Hillel, 1995).

The annual rainfall and the trend over the last 20 years are shown in Figure 1. Annual rainfall ranged from a low of 345.4mm in 1992 to a high of 1475mm in 1997. The rainfall amount decreased sharply to 560 mm in 1998, and continued to vary until 2002. Between 2002 and 2004 the rainfall amount became relatively stable but this stability was altered in 2005 which received 1275 mm. Since 2006, total annual rainfall has continued to decline. The mean annual rainfall for the period was 987.4 mm. This value falls in the range given by Asamoah (1983) which is between 900 mm along the coast to between 1100 mm and 1600 mm in the hinterland. The trend line for the period shows that annual rainfall amount is increasing. This is probably due to the very low rainfall amounts experienced before 1994. A trend line for after 1994 will show that rainfall has been decreasing. Towards the end of the period under study, variation of rainfall amount from the mean appeared to be getting smaller.

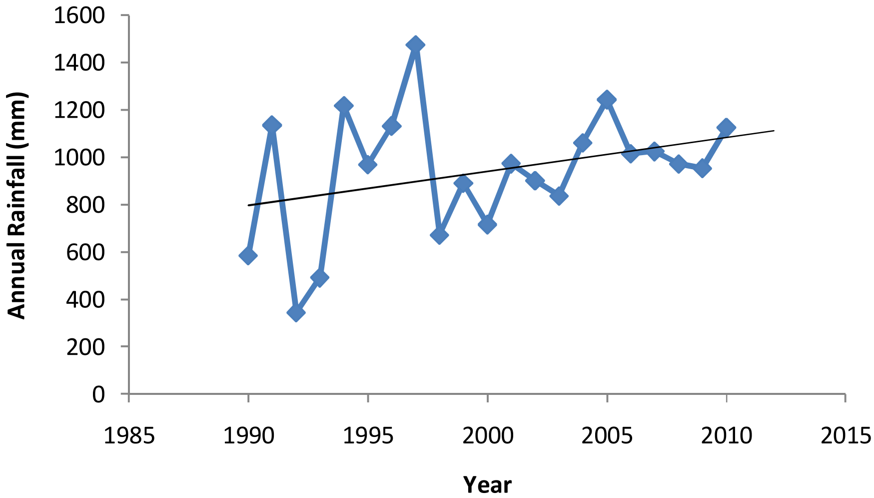

Figure 1 Variation in Annual Rainfall

Peak Monthly rainfall

The maximum amount was in 1991 which was 433.4mm and the lowest amount in 1993 which was 126 mm. The trend line shows that peak monthly rainfall is on the increase. It is interesting to note that the peak amount occurs eleven times in June, seven times in May, and two times in October.

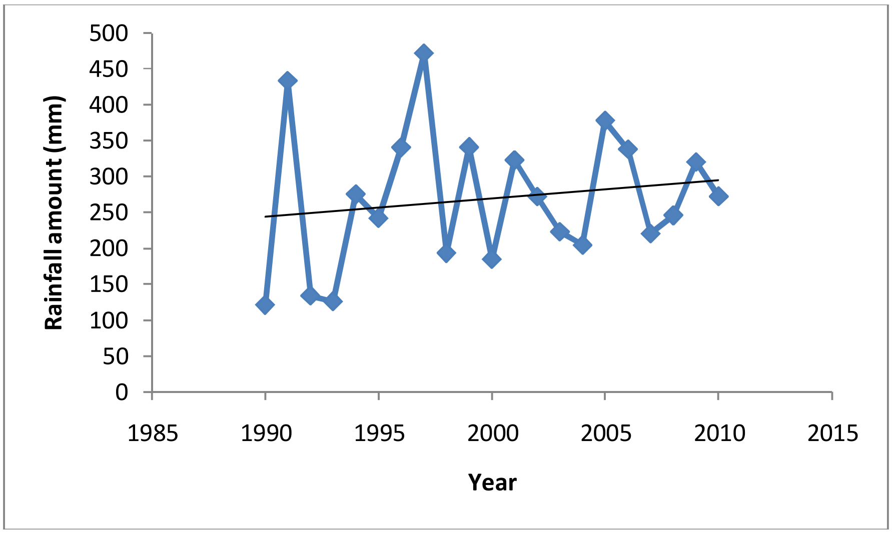

Figure 2 Peak MonthlyRainfall Amounts

Date of onset of rainfall

According to Laux et al. (2008) approximately 70% of the West African inhabitants depend on rainfed agriculture, but rainfall is limited to few months per year. As the rainy season is short, it is important to sow as early as possible to avoid wasting valuable growth time. The reliable determination of the 'Onset of the Rainy Season' (ORS) is therefore of crucial importance for sustainable food production. Due to a misinterpretation of the ORS, wrong decisions of planting date lead to crop failure and high economic losses within the Volta basin. In addition, farmers have reported an increasing variability of the ORS, especially since the 1980s.

The Julian date, (a date expressed as the number of days since January 1 of the current year) for the onset of the rainy season is presented for the twenty years. The onset of the rainy season is determined by a method proposed by Kasei and Afuakwa. (1991) which was that of receiving a total of 30 mm of precipitation within 10 days after which there is no dry spell longer than 7 days within the next 30 days.

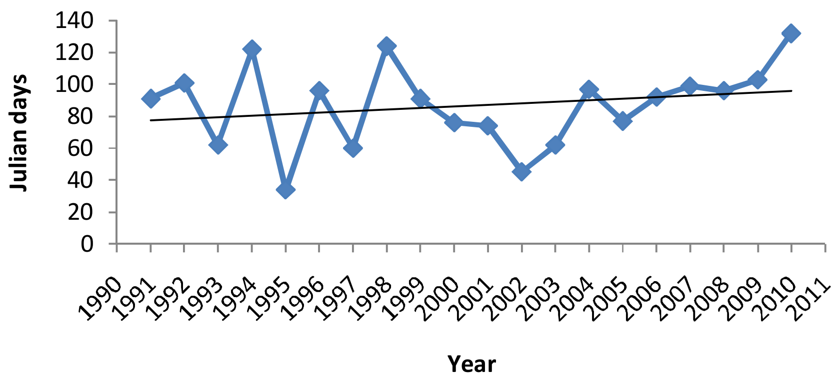

Figure 3 Date of Onset of Rainfall

The rains start nine times in April and five times in March. Abban (1985) however indicates that the onset of the major rainfall season mostly occurs in March. There is the indication that a change has occurred in the date of onset of rainfall. The plot shows an increasing trend indicating that the rains are on the average coming later than previously..

Mean Temperature

Higher temperatures could increase the rate of microbial decomposition of organic matter, adversely affecting soil fertility in the long run. Also, temperature increases may extend the geographic range of some insect pests currently limited by temperature (Parry, 1990) which could lead to the loss of crops.
According to Rosenzweig and Liverman (1992) an analysis of the biophysical impact of climate changes associated with global warming shows that higher temperatures generally hasten plant maturity in annual species, thus shortening the growth stages of crop plants. Temperature benefits crop production by enhancing photosynthesis thereby increasing crop yield as it increases (Rosenzweig and Hillel, 1995).
IPCC (2007) indicates that an increase in average temperature can do the following: lengthen the growing season in regions with a relatively cool spring and fall; adversely affect crops in regions where summer heat already limits production; increase soil evaporation rates, and increase the chances of severe droughts.
When temperatures exceed the optimal for biological processes crops respond negatively with steep drop in net growth and yield (Ofori-Sarpong, 2001).
The years which recorded the lowest temperature were 1999 and 2001 (25.7 ^{0}C) and the highest temperature for the period was recorded in the year 1990 (27.3 ^{0}C) . The mean temperature for the period was found to be 26.4 ^{o}C. Asamoah (1973), however stated that the mean temperature for the Mfantseman area was 23.5 ^{o}C. This indicates that there has been an increase in temperatures in the study area. This is in line with studies conducted on temperatures for a number of stations in Ghana which indicate that temperature is generally increasing (Ontoyin, 1993).

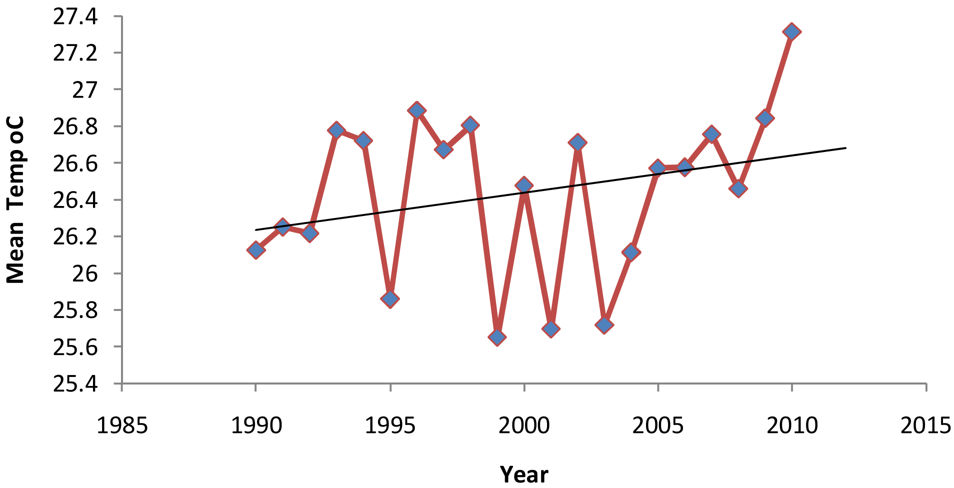

Figure 4 Variations in mean temperatures

As temperature increases so does the process of evaporation. In addition the moisture holding capacity of the atmosphere increases with temperature. For every 1^{o}C increase in global temperatures there is a 7% increase in the moisture holding capacity of the atmosphere, and more moisture in the atmosphere ultimately leads to changes in rainfall patterns (WATCH, undated).

Mean Evaporation

Evaporation is an important process in the global water cycle. It acts like an air conditioner for the earth surface because heat is used when water enters the atmosphere as moisture. But at the same time, water vapour acts as a green house gas by trapping radiation in the lower atmosphere (WATCH, undated).
Evaporation is dependent on four main factors, namely; radiation balance, humidity, temperature and wind (Allen *et al.*, 1998). The declining trend in evaporation is an indication that these four factors, bulked together must have a decreasing trend.
The lowest evaporation values recorded was 2.1mm and highest was 2.7mm. As evaporation leads to soil water loss, the greater the value, the less moisture available for crop production.

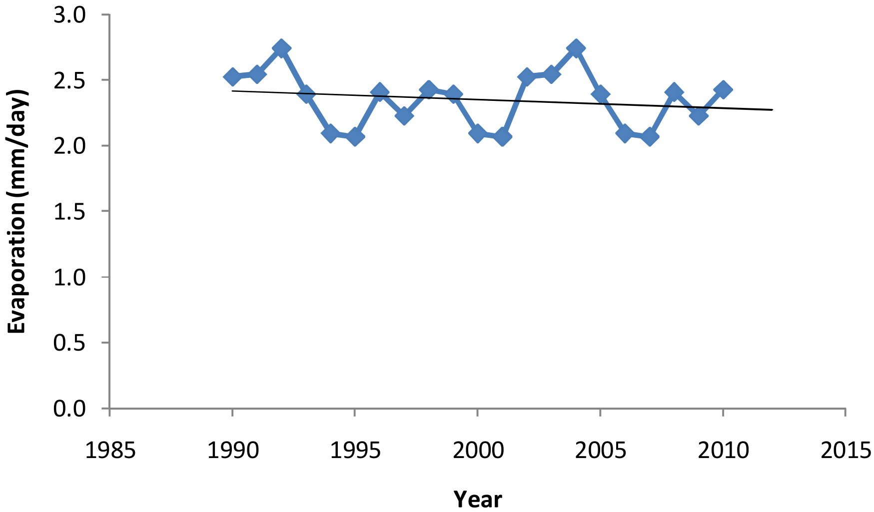

Figure 5 Mean Evaporation rates

Crop Water Requirement

Figure 5 shows crop water requirement (ETc) and irrigation water requirement (Irr Req) for maize over the period under consideration for determined ORS. The highest ETc recorded was in 1995 (451.9mm) and the lowest in 2009 (319.2mm). The highest irrigation requirement was in 1998 (211.2mm) and the lowest was in 2003 (6.8 mm). The trend lines show that maize crops are using no more water today than in the past; however, interestingly irrigation requirement is on the decline.

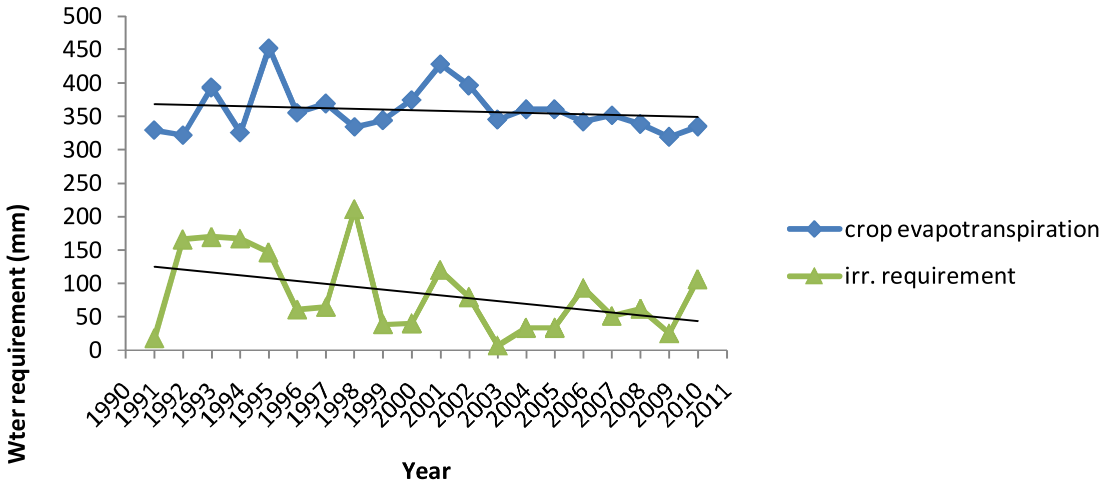

Figure 6 Crop Water Requirement (Etc) and Irrigation Requirement (Irr Req) for maize for determined planting date

Irrigation requirement and crop water requirement when 1st March was used as the planting date are shown in Figure 6. The highest ETc recorded was in 1994 (453.1mm) and the lowest in 1997 (366.9mm). The highest irrigation requirement was in 2007 (306.1 mm) and the lowest was in 1992 (0 mm). The trend lines show that water requirement for maize decreased over the period however, irrigation water requirement increased. This could be due to the rainfall amounts obtained decreased over the period from 1994 (see Figure 1).

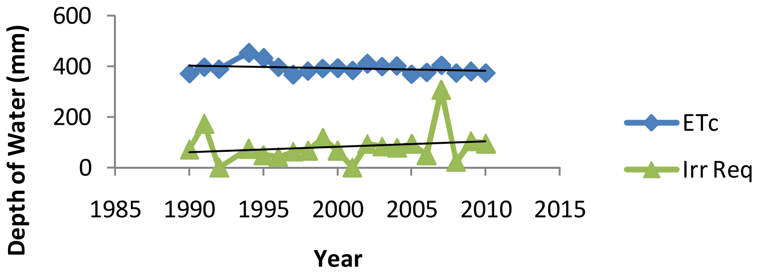

Figure 7 Crop Water Requirement (ETc) and Irrigation Requirement (Irr Req) for maize for 1st March planting date

Crop Yield
For determinate crops, temperature shortens their productive stage, decreasing the time of canopy existence and hence the period during which they receive light and produce biomass. In the case of indeterminate crops, the canopy continues to intercept light until it is reduced by events such as pest infestation. Therefore, an increase in temperature beyond the base but not exceeding optimum temperature range for plant growth and development should lead to lower yields in cereals and higher yield in root crops. However, higher temperature may also lead to higher rate of evaporation and hence reduce moisture availability that can be expected to affect yield (Porter, 1990).

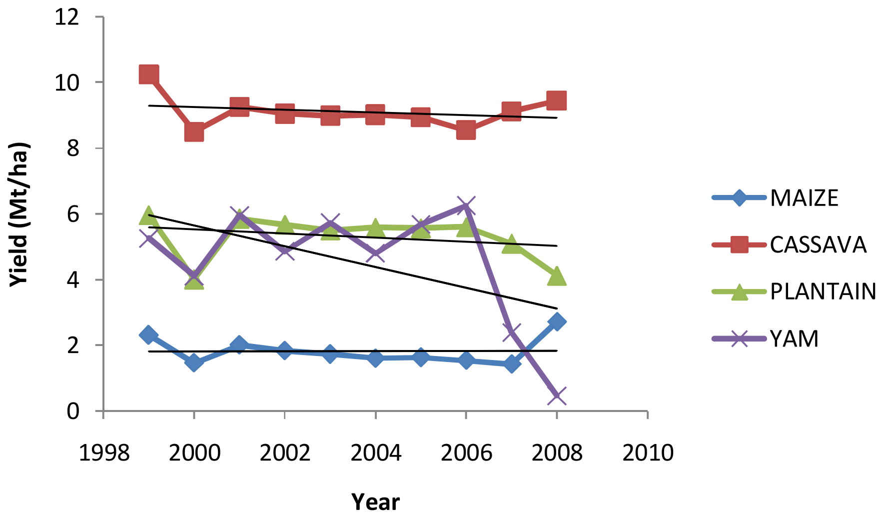

Figure 8 Average yield of major crops grown (Mt/ha)

Assessment the average yield of the various crops reveals that the yield of most of the crops has been decreasing over the years. This trend may be as a result of either the decreasing total annual rainfall or the increasing mean temperatures or both. Extreme temperatures are important because many crops have critical thresholds both above and below which crops are damaged. Prolonged hot spells can be especially damaging (Mearns *et al.*, 1984). Critical stages for high temperature injury include seedling emergence in most crops, silking and tasseling in corn (Shaw, 1983).
The yield of maize were quite low when compared to the yields of the other major crops. This may be the difference in the tolerance of the crop to moisture stress. Cassava is known to perform better in a wide range of total annual rainfall and it could tolerate drought to a greater extent than maize. Maize is very sensitive to moisture stress especially during the tasseling and silking stages and therefore will not give good yield if the moisture content is low. This condition is applicable to plantain and yam; they also have different tolerance levels to moisture (Haws *et al.*, 1983).

CONCLUSIONS

Rainfall has been fluctuating within the 20 years with extremes of 345.4 mm and 1475 mm and appears to be decreasing. The ORS has shifted from March dominance to April dominance. Mean temperatures have been increasing steadily but interestingly, mean evaporation values have been decreasing steadily. Water requirement for maize has been declining over the period, and yields of the major crops grown in the area have been declining and this may be due to the variations in the climatic elements especially rainfall and temperature. From the trends shown in the climate elements one can conclude that there has been little change in the climate of the Mfantsiman area but it cannot be concluded that this has affected crop production.

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