ARPN Journal of Agricultural and Biological Science
©2006-2011 Asian Research Publishing Network (ARPN). All rights reserved.

ASSESSMENT OF CLIMATE SHIFT AND CROP YIELDS IN THE CAPE COAST AREA IN THE CENTRAL REGION OF GHANA

J. D. Owusu-Sekyere[1], M. Alhassan[1] and B. K. Nyarko[2]
[1]Department of Agricultural Engineering, University of Cape Coast, Ghana
[2]Department of Geography and Regional Planning, University of Cape Coast, Ghana
E-Mail: jaydosus@yahoo.com

ABSTRACT

The aim of the study was to assess the variability and trend of major climatic elements in the Cape Coast metropolis and the possible impact of these changes on the yield of major crops produced in the metropolis. Climatic data covering a period of sixteen years (1993-2008) was obtained from the Ghana Meteorological Agency, Cape Coast. Crop yield data spanning a period of eight years (2000-2008) was obtained from the Ministry of Food and Agriculture (MoFA), Cape Coast. Probability analysis of rainfall data was also used to predict the probability of occurrence and exceedance of rainfall of a certain amount in the future as well as the return period. The study revealed that over the period under scrutiny, temperature and evaporation have been increasing gradually, it was also discovered that peak monthly rainfall is also declining and there is a higher probability of lower amount of rainfall occurring in the future.

Keywords: climate change, crop yields, temperature, evaporation, rainfall prediction.

INTRODUCTION

In recent times, there has been a significant concern about the impact of climate change and its variability on agricultural production the world over. This global response stems from the realization of the fact that the severity and pace of climate change, in contemporary times, is presenting new challenges which require urgent attention. Today, issues of food security and crop yields feature prominently in the list of human activities and ecosystem services under threat of dangerous anthropogenic interference on Earth's climate (IPCC, 2001). As a result, each country is naturally concerned with potential damages and benefits that may arise over the coming decades from climate change impact on its territory, since these will affect domestic and international policies, trading patterns, resource use, regional planning and ultimately the welfare of its people.

According to Welbergen *et al*., (2008), Climate Change is any long-term significant changes in the 'average weather' of a region or the earth as a whole. Average weather may include average temperature, precipitation, relative humidity, evaporation, solar radiation and wind patterns among others. These changes can be caused by dynamic processes on Earth, external forces including variations in sunlight intensity and, more recently by human beings. Climate change resulting from human activity has the potential to substantially affect agricultural systems (IPCC, 2001).

Climate change affects agriculture and food production in many complex ways. It largely defines the climax vegetation formations throughout the world and so sets the limit for crop production. Crop production would thus have to adapt to changing climatic regimes to be able to sustain high productivity.

Climate changes have a direct influence on the quantity and quality of crops produced and in many cases, negatively affects it. It affects the suitably of land for different types of crops and pasture; it has a devastating effects on the health and productivity of crops, forest, the incidence of pest and diseases, biodiversity and ecosystem (FAO, 2008).

Climate change and variability may result in irreparable damage to arable land and water resources in some regions with serious local consequences for food production. These losses will be experienced most seriously in developing countries with low capacity to adapt. Climate change affects food production directly through changes in agro-ecological conditions and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural produce.

The greatest damage from climate change is predicted to be in the agricultural sector in Sub-Saharan Africa for a number of reasons; Agriculture is predicted to be especially vulnerable in this region because:

- The region already endures high heat and low precipitation.
- A significant number of the agricultural population relies on relatively basic technologies.
- Widespread poverty, which leads to low per capita food production in most African countries, limits the capacity of farmers to embrace adaptive measures to mitigate the adverse effects of climate changes (UNMP, 2005).
- Recent studies by various researchers have shown that most of the recent problems of food security have resulted from weather related hazards and extreme weather events such as drought and flood (McCarthy *et al*., 2001). This may partly explain why linkages between development and climate change are starting to receive more and more attention in scientific and policy circles.

Although the focus of the international community is on climate change mitigation, the issue of adaptation to climate change is an equally pressing issue and must be given the due attention and consideration.

©2006-2011 Asian Research Publishing Network (ARPN). All rights reserved.

This is of critical importance to many developing countries that have contributed little to greenhouse gas emission, since it is these countries that will bear the brunt of the negative impacts of climate change and variability (UNMP, 2005).

In this paper, an attempt has been made to look at the link between climate change and crop yields or better still, the impact of climate change on the five most commonly produced crops in the Cape Coast metropolis namely; maize cocoyam, cassava, yam and plantain. Assessing the correct relationship between changes in the various climatic elements and yields for these major crops is a critical first step before more elaborate models can be used to estimate how crop choices, food supply and prices might shift in response to climate change.

MATERIALS AND METHODS

Area description

Cape Coast Metropolis lies within latitude 5.07 º to 5.20 º North of the Equator and between longitudes 1.11º to 1.41º West of the Greenwich Meridian. The metropolis covers a total land area of approximately 122 sq.km (12,200 ha) and has a total population of 118,106 out of which 57,365 are females and 60,741 males. Farmers and fishermen as well as those into agricultural-related activities form about 60% of the population. Active agricultural population is approximately 99.7%. The available cultivable land for agriculture is about 8,000 ha (MoFA, 2000). Vegetation is mainly secondary forest with thickets and shrubs growing to an average height of 4.5m. There is a coastline which is about 13km long. According to Asamoah (1973) temperatures range between 24ºC and 32ºC with relative humidity ranging between 70% and 90%. The region experiences bimodal rainfall regime with peak in May-June and October. The annual total rainfall ranges between 900mm along the coast to between 1100mm and 1600mm 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.

Climate data

Data was obtained form the Ghana Meteorological Station, Cape Coast, for four climatic elements namely temperature, relative humidity, evaporation and precipitation. Data for each elements covered a period of sixteen years (1993-2008) with the exception of relative humidity which was up to fifteen years.

Crop yield data

The major crops produced in the Cape Coast metropolis and their respective yields were obtained from the Ministry of Food and Agriculture (MoFA), Cape Coast. The values obtained were average yields of the crops in tons per hectare spanning a period of eight years (2000-2008). The major crops produced in the metropolis include maize, plantain, cassava, cocoyam and yam.

Method of data analysis

The data obtained were analyzed using tables and line graphs. Trend lines were also introduced to find the general trend or pattern over the period under consideration. The analysis from the tables and graphs were used to determine the variation in mean annual temperature and evaporation, the variation in annual and peak monthly rainfall, the onset date of rainfall in a given year, the probability of occurrence of rainfall and the return period of a given amount of rainfall.

The probability of occurrence of rainfall

This was determined using the formula below:

$$P(\%) = \frac{m - 0.375}{N + 0.25} \times 100 \qquad \text{.....................} (1)$$

Where

P is the probability in % of the observation of the rank, m is the rank of the observation and N is total number of observations used.

The return period of a given amount of rainfall was calculated using the formula:

$$T(years) = \frac{100}{P} \qquad \text{.....................} (2)$$

Where

T is the return period in years and P is the probability in % of the observation of the rank.

Onset date of rainfall

The onset date is when rainfall is not less than 25.0mm and there are no dry spells for more than 7 days within the next 30 days. This method is according to (Kowal and Sivakuma, 1988) and is called the hybrid method.

RESULTS AND DISCUSSIONS

Figure-1 shows the mean annual rainfall pattern in the Cape Coast metropolis for the past sixteen years.

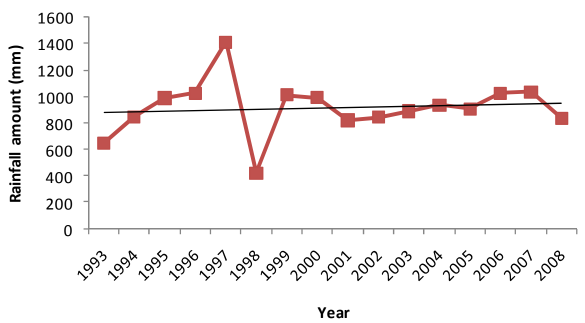

Figure-1. Mean annual rainfall and trend line (1993-2008).

As can be observed, there was some level of consistency in the rainfall pattern from 1993 until when the peak was recorded in 1997 with an amount of 1411.8mm, this reduced drastically to 417.3 in 1998.

©2006-2011 Asian Research Publishing Network (ARPN). All rights reserved.

Between 2001 and 2004, the rainfall amount continued to increase steadily but has been varying significantly since 2004. The mean rainfall for the period was 913.6mm. The trend line indicates that the rainfall pattern has been stable and has not experienced sharp increases or decreases over the last sixteen years.

The second lowest rainfall was obtained in 1993 with an amount of 647 mm. According to Asamoah (1973), mean annual rainfall in the Cape Coast metropolis range between 900-1600mm and the annual mean is 940.1mm.

However, in this study, mean annual rainfall was discovered to range between 417.3-1411.8mm. The mean annual value has also declined to 913.6mm. This drastic reduction between the highest and the lowest annual rainfall could be the result of a changing climatic condition in the metropolis.

Figure-2 shows peak monthly rainfall for the period 1993-2008.

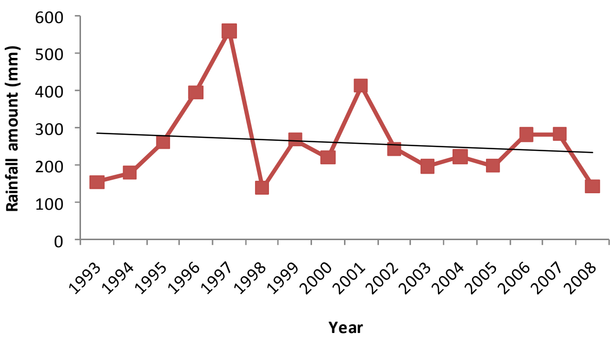

Figure-2. Peak monthly rainfall and trend line (1993-2008).

It is clear that between 1993 and 2001, peak monthly rainfall followed the same pattern as that of the mean annual rainfall. Here too, the highest peak monthly rainfall was obtained in 1997 with an amount of 879.9mm followed by 1996 with an amount of 757.0 mm. The lowest again occurred in 1998 with an amount of 188.7mm. Too little rainfall can adversely affect crop yields, especially if dry periods occur during critical developmental stages such as flowering, pollination, and grain-filling. Unlike mean annual rainfall, peak monthly rainfall assumed a decreasing trend from the year 2000 to 2005. From 2005 to date, the pattern has been varying greatly implying that there has not been stability in peak monthly rainfall since 2005. Unfortunately, the trend line in Figure-2 indicates that peak monthly rainfall has been decreasing slightly over the past sixteen years.

The decline in peak monthly rainfall may be due to a number of factors among which includes deforestation and changes in sea surface and atmospheric conditions. Deforestation in particular tends to increase the surface albedo which sets up subsidence in the atmosphere above reducing rainfall (Ofori-Sarpong, 1998).

Table-1 shows the onset date of the major rainfall season. Over the last sixteen years, the onset date occurred in March 8 times. This observation confirms Abban (1985) work which indicated that the onset dates of the major rainfall season mostly occurs in March.

Table-1. Onset of the rainy season (1993-2008).

Year	**Onset date**	**Amount of rainfall** (mm)
1993	29th March	26.8
1994	2nd May	86.5
1995	8th March	30.0
1996	19th April	33.4
1997	14th March	59.9
1998	4th May	63.1
1999	12th March	31.5
2000	20th March	55.9
2001	18th April	32.2
2002	23rd February	49.6
2003	25th March	41.8
2004	16th March	49.4
2005	6th February	30.9
2006	2nd April	39.8
2007	8th March	25.8
2008	10th May	35.5

Due to lack of knowledge and inaccurate information on how to determine the onset date, some farmers often consider any rainfall event in the major season as the beginning of the rainy season. For example, it was observed that, in 2002 and 2005, the season actually began in February which forms part of the dry season. In situations like this, due to the early onset of the rains, farmers might be deceived to still delay planting until the normal date by which time there would have been abrupt cessation of the rainy season. This has a high tendency of making the growing season too short for crops to give good harvest (Ofori-Sarpong, 1998). Also, in 1994, 1998 and 2008, the rainy season started in May. This is a shift in the month on which the rainy season begins. Changes in the onset of rainfall date, whether gradual or rapid, has the tendency of altering the normal rainfall pattern and can seriously affect crop yields (Ofori-Sarpong, 1998).

Rainfall probability analysis (Table-2) is a method used to determine the probability or frequency of occurrence of yearly or seasonal rainfall for the design of water harvesting schemes. For instance, a farmer can take advantage of the total annual or peak monthly rainfall expected by providing only the additional water needed by the crops to obtain maximum yield. The table shows the probability of a given amount of rainfall that will be exceeded or equaled in the future. For instance, the probability that a rainfall amount of 879.9mm will be equaled or exceeded in the Cape Coast metropolis is 3.8%.

 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

©2006-2011 Asian Research Publishing Network (ARPN). All rights reserved.

www.arpnjournals.com

Similarly, the probability that a rainfall amount of 188.7mm will be equaled or exceeded in the Cape Coast metropolis is 96.2 %. This amount of rainfall can be expected in 9 out 10 years. Once the exceedance is known, the return period in years can be calculated. The indication here is that, lower amount of rainfall have higher probability of recurring in future than higher amount of rainfall. For example, a low rainfall amount of 301.0mm is more likely to occur that a higher amount of 879.9mm in the Cape Coast metropolis.

Table-2. Ranked peak monthly rainfall (1993-2008).

Year	**R** (mm)	**m**	**P** (%)	**T** (years)
1997	879.9	1	3.8	26.3
1996	757.0	2	10.0	10.0
2006	639.4	3	16.2	6.2
1995	601.5	4	22.3	4.5
2001	591.2	5	28.5	3.5
2008	580.1	6	34.6	2.9
1999	574.3	7	40.8	2.5
2000	527.7	8	46.9	3.5
2002	523.1	9	53.1	2.9
2003	453.1	10	59.2	2.5
2004	453.4	11	65.4	2.1
2005	368.9	12	71.5	1.9
1994	363.6	13	77.7	1.7
2007	360.3	14	83.8	1.5
1993	311.2	15	90.0	1.1
1998	188.7	16	96.2	1.0

This observed trend may be attributed to the gradual change in the climatic pattern of the metropolis (Ofori-Sarpong, 2001) implying that in the future, the Cape Coast metropolis would record lower amount of rainfall than is now the case. This situation paints a gloomy picture about agricultural productivity in the future, since a low peak seasonal rainfall can have devastating influence on crop yields in the metropolis.

The graph in Figure-3 depicts mean annual temperature over the last sixteen years. It shows that temperatures in the metropolis have been varying greatly. It assumed an increasing trend from 2000 to 2003. It then decreased in 2004 and increased again up to 2006. The highest temperature was recorded in 1998 (28.6ºC) which was the year with the lowest amount of rainfall and the second highest was obtained in 1996 and 2003 (28ºC) respectively. The lowest temperature was obtained in the year 2000 (25.9ºC) followed by 1995 (27.2 ºC). The trend line indicates that temperatures in the metropolis have been increasing over the period under study. According to Abban (1985), temperature in the Cape Coast metropolis ranges from 24-32 ºC (i.e., minimum and maximum) with an annual mean of 23.5 ºC. However, the findings of this research revealed that, temperatures range between 23.2-33.2 ºC with an annual mean of 27.6 ºC. The trend line in Figure-3 further indicates that temperatures have been increasing over the past sixteen years, confirming a research conducted by Ontoyin (1993), who discovered that temperatures are generally on the increase. This increase in temperature may accelerate the rate at which plant release carbon dioxide in the process of respiration, resulting in less than optimal conditions for net growth (Ofori-Sarpong, 2001). Wide fluctuations in mean annual temperature can affect crop production a great deal. Hence, any change in temperature can result in yield reduction. In general, the observed trend may be part of the global warming due to the green house effect (Ofori-Sarpong, 1998).

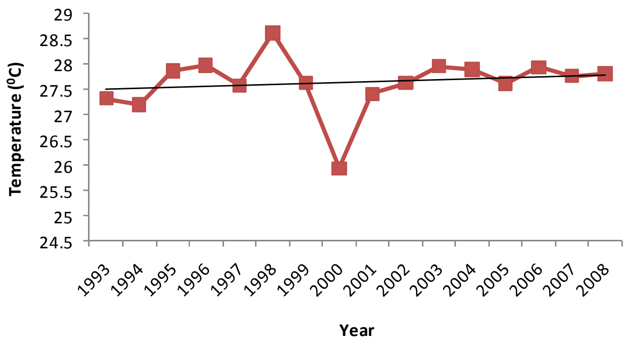

Figure-3. Mean annual temperature and trend line (1993-2008).

From Figure-4, the highest evaporation rate occurred in 1999 (2.6mm) and the second highest was 2.5mm in 2006. The lowest evaporation rate for the period was recorded in 1995(1.8mm). The trend line shows that evaporation rate has been on the increase.

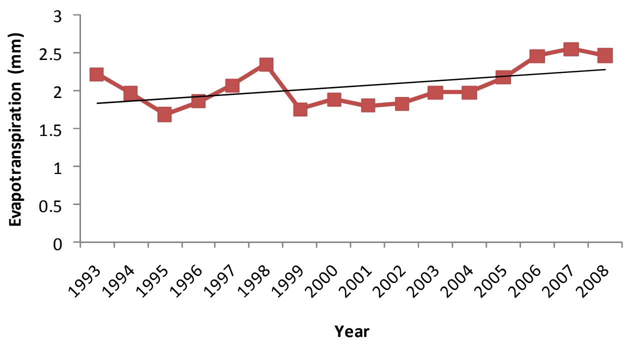

Figure-4. A graph of mean annual evaporation and trend line (1993-2008).

The increasing trend of evaporation might have been influenced by the high temperatures.

Fluctuations in agricultural production are mostly attributed to changes in the climatic elements of rainfall and temperature. Farmers in the Cape Coast are mainly

VOL. 6, NO. 2, FEBRUARY 2011 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science
©2006-2011 Asian Research Publishing Network (ARPN). All rights reserved.
www.arpnjournals.com

subsistence farmers who rely basically on rainfall and small-holdings for crop production. Therefore, any change in major climatic elements such as rainfall and temperature will adversely affect agricultural productivity. Table-3 indicates that, in general, irrespective of the variety, yields of all major crops have been declining since the year 2000. In year 2000, for example, total annual output of maize was 1.9Mt/ha. This value declined to 1.75, 1.58 and 1.02 Mt/ha in 2001, 2002 and 2003, respectively. The same trend can be observed in the case of the other crops and may be the result of either decreasing peak monthly rainfall or increasing mean temperatures or a combination of both (Ofori-Sarpong, 2001).

Table-3. Average yield (Mt/ha) of major crops in the Cape Coast metropolis (2000-2008).

Year	Maize	Cassava	Yam	Cocoyam	Plantain
2000	1.90	15. 2	5.90	5.10	6.57
2001	1.75	17.1	5.22	4.33	6.50
2002	1.58	17.2	4.50	4.31	6.82
2003	1.02	16.79	4.41	4.11	6.82
2004	1.56	16.80	4.32	3.97	5.80
2005	1.40	16.20	3.92	2.98	4.75
2006	0.99	15.80	3.89	4.18	5. 86
2007	1.20	17.70	0.99	4.12	5. 70
2008	1.52	7.49	2.00	4.10	0.00

Figure-5 shows that mean annual relative humidity for the past sixteen years has been fluctuating between high and low values. Asamoah (1973) indicated that, relative humidity in the Cape Coast metropolis ranged between 70-90%. However, it was found in this study that relative humidity ranged between81.3-84.4%. The highest value was recorded in 2001 (84.4 %) and the lowest occurred in 1999 (81.3%). High relative humidity reduces the rate at which plants lose water through transpiration (Baker, 2004).

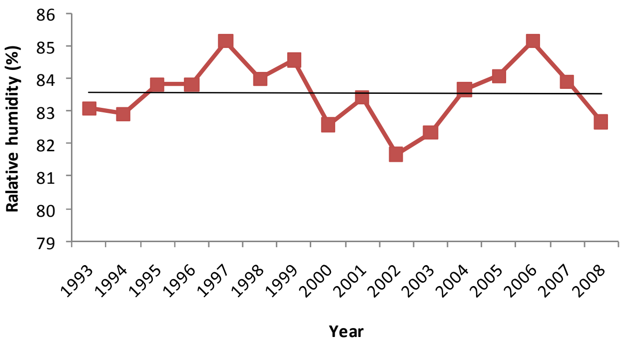

Figure-5. A graph of mean relative humidity and trend line (1993-2008).

CONCLUSIONS

The following conclusions were drawn after the case study in the Cape Coast metropolis;

a) Total annual rainfall was found to range between 417.3-1411.8mm. Since 1997 the rainfall pattern has not been stable but fluctuates between high and low values;
b) Onset of the rainy seasons also fluctuates between March and April and the frequency of rainfall has been declining over the years;
c) There is a gradual decrease in peak monthly rainfall and relative humidity as well as increase in temperature and evaporation which is a clear indication of a changing climate;
d) Rainfall amount is more likely to reduce in the future; and
e) Yields of all major crops in the metropolis have been declining gradually over the past 16 years due to the gradual change in the pattern of the major climatic elements.

ARPN Journal of Agricultural and Biological Science
©2006-2011 Asian Research Publishing Network (ARPN). All rights reserved.

REFERENCES

Abban GK. 1985. Analysis of data from University of Cape Coast weather station. Dissertation. Department of Geography, U.C.C. p. 45.

Asamoah GK. 1973. Soils of the proposed farm sites of the University Of Cape Coast. Soil Research Institute Technical Report No. 88.

Baker JT. 2004. Yield responses of southern US rice cultivars to CO_2 and temperature. Agricultural and Forest Meteorology.122: 129-137.

F.A.O. 2008. World Food Security-The Challenge of Climate and Biodiversity. FAO publication, New York. pp. 191-2000.

Inter-governmental Panel on Climate Change (IPPC). 2001. Climate Change, Impact and adaptation. U.K. Cambridge University Press. p. 29.

Kowal CL and Sivakumar JB. 1988. Prediction of onset date of rainfall in the tropics. Science. 215(5963): 307-410.

McCarthy J, Canziani OF, Dokken DJ. 2001. Climate change, impacts, adaptation and vulnerability. Contribution of workshop Group II to the assessment report of the Intergovernmental Panel on Climate Change.

Ofori-Sarpong E. 1998. Climatic effect of deforestation in some parts of West Africa. Legon journal of the humanities. 11: 103-108.

Ofori-Sarpong E. 2001. Impacts of climate change on agriculture and farmers copying strategies in the Upper West region. West African Journal of Applied Ecology. 1: 27.

Ontoyin Y. 1993. Comparative study of temperature as a climate indicator for periods 1931-1960 and 1961-1990. Conference proceedings as change and its impacts on water oceans, fisheries and coastal zone. pp. 99-153.

UN Millennium Project. 2005. Millennium Ecosystem Assessment Ecosystems and human well-being: synthesis. Island Press, Washington DC. Paper No. 183.

Welbergen J.A, Klose S.M, Mark W.N.N. and Eby P. 2008. Climate change and the effect of temperature extremes in Australian flying flocks. Proceedings of the Royal Society B. Royal Society Publishing Inc. pp. 304-410.