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CLIMATE CHANGE AND ITS IMPACT ON AGRICULTURAL PRODUCTION – A CASE STUDY IN THE TOLON DISTRICT OF GHANA

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Abstract
This study was done in Sabegu in the Tolon District of the Northern Region of Ghana to determine the extent to which two key climatic factors, temperature and rainfall, have changed and their impact on agriculture. Temperature and rainfall data in the District over a period of twenty-one years (1995 – 2015) were gathered and analyzed. In addition, data on pepper production for three consecutive years (2013-2015) were gathered from forty-one pepper farmers using a simple random sampling method. Statistical Package for Social Sciences (SPSS) was utlized to analyze the gathered data and the results were interpreted and presented in simple descriptive statistics format. Results of the research, based on yield data provided by the farmers, indicate that with an increase in average annual temperature from 27.1°C to 27.9°C and a decrease in annual rainfall from 1000 mm to 900 mm there was a yield reduction of the crop by about 24% between 2013 and 2015.

Keywords: ***Climate change, Temperature, Rainfall, Impact, Pepper production***

Introduction

Climate change is a modification in the climatic state identified (using statistical test) by transformations in the average and the variations of climatic conditions occurring over long periods of time, usually decades (IPCC, 2011). The term 'climate' pertains to statistical data such as the means of all weather occurrences gathered over decades (Kropp and Scholze, 2009). Weather is the atmospheric condition at a specific time, whereas climate is what statistics tell us at any given point in time of the year Oreskes *et al.,* 2010).

Climate change can be as a result of natural internal happenings or external factors including variations in the sun's movements, volcanic actions as well as persistent anthropogenic vicissitudes in atmospheric structure or in the uses of land (IPCC, 2012). Sayemuzzaman *et al.* (2014) assert that rainfall and temperature are the two utmost significant climatic factors that effect plant growth.

Climatic occurrences and data gathered from research showed that mean temperatures of the world started rising from the mid-19th century, with the highest increase occurring from the mid-1970s onwards (IPCC, 2014). According to IPCC (2007), anthropogenic influences continue to be the main reason for current extreme climatic happenings. Owing to the accumulation of the greenhouse gases in the atmosphere, temperature continuously increases resulting in changes in global rainfall patterns (Parry *et al*., 2007).

The mean annual temperature (MAT) within the entire Yangtze basin of China between 1955 and 2011 was 14.0 °C, and ranged from 13.4 °C to 14.9 °C. This vast change in temperature indicates that temperatures are continuously increasing (Chen *et al*., 2014). Following the varying climatic patterns for the last decade, the mean temperature in Ghana between 2010 and 2050 was projected to vary between 34 °C (in the west forest zones) and 41 °C

(in the dry north savannah zones) (World Bank, 2010). These suggest that the global climatic pattern, particularly in sub-Saharan Africa, continues to worsen with adverse effects on the environment as well as agriculture (Brown *et al*., 2010).

In Ghana, climatic trends were predicted to rise every 30 years from 1920, 1950 and 1980 with espective temperature incrases of 0.6, 2.0 and 3.9 - 4.0 °C (Minia, 2008). Such predictions of climatic pattrerns thus called for further research to be undertaken to find solutions to the climatic issues. Petrie *et al.* (2014) proved in their research at northern Chihuahuan Desert, United States, that regional rainfall shows patterns in mean occurrence and amount. In the case of Ghana, research has revealed that the yearly precipitation in the country is extremely capricious on inter-yearly and inter-decadal periods, which make long-term predictions cumbersome. However, there were particularly high amounts of rainfall in Ghana in the 1960s, and these reduced to small amounts from the late 1970s and early 1980s onwards. This resulted in a complete falling pattern from 1960 to 2006 of a mean of 2.3 mm per month or 2.4 % per decade (McSweeney *et al.,* 2008). In addition, another study conducted by Dontwi *et al.* (2008) with regards to the coastal parts in Ghana shows a substantial direct decreasing trend between 1961 and 2000 (a reduction of approximately 1000 mm) with a recurring low and high rainfall years within an ostensible six-year interval.

An assessment of the average yearly rainfall variations at all meteorological stations in Ghana between 1951-1970 and 1981-2000 similarly show a reduced amount of rainfall (Stanturf *et al.,* 2011). Decreased amounts of rainfall in Ghana between 1981 and 2000 could somewhat be due to the extreme drought situation that occurred in 1983 in the country, which resulted in starvation and hunger with a lot of people fleeing to other areas of the globe for survival (Armah *et al.,* 2011). Growth of plants is affected by decrease in rainfall. In this regard, there are growing concerns that such reductions in rainfall among sub-Saharan African countries could countinuously make the food security situation worse as agricultural production in Africa is mainly dependant on raifall (Hendrix and Glaser., 2007).

Problem Statement and Justification

According to Zatyko (2006), pepper use dates back to 7000 B.C. The domesticated taxa now have a worldwide distribution but as at the time Christopher Columbus discovered the New World, they were much more narrowly distributed. The importance of pepper is enormous. It is a predominantly used ingredient in Ghana and many cannot enjoy a meal (especially fresh fish) without it. It is either eaten fresh (as with kenkey) or in sauce, stew, soup and it is generally used as flavour. It is indicated by Parthasarathy *et al.* (2008), that pepper is an important export crop and has a high domestic demand.

Food crop production is important in ensuring food security and sustainable livelihoods. Agriculture in northern parts of Ghana is nevertheless beset with numerous challenges. Climate variability is the most critical and to some extent irreversible with both anthropogenic and natural causes (Amikuzuno and Donkoh, 2012). A vast majority of the rural poor in sub-Saharan Africa continue to rely on farming as their main means of living. Constant threat of food insecurity and loss of livelihood results from low yields in the case of crop production and this leads to increased incidence of morbidity and mortality in the case of livestock production (Wood, 2013).

Climatic variations intrinsically affect the agricultural sector and globally it is the greatest susceptible sector to the impacts as well as risks associated with climate change (IPCC, 2007). It is predicted that high temperatures will result in reduced yields in crops (Apata *et al.,* 2010). Unimodal patterns of rainfall experienced in the region coupled with climate change make it challenging for farmers in the Northern Region to produce sufficient yield levels of crops to meet consumption demand of the region and the country in general (Amikuzuno and Donkoh, 2012).

The main problems facing pepper farmers in Sabegu are drought, increasing temperatures and decreasing soil fertility (Shu-aib Jakpa and Owusu, 2018). Pepper farming in Sabegu is mainly rain-fed with low external inputs. There is therefore the need to find out the extent to which the climatic factors, particularly temperature and rainfall have changed,

leading to their adverse impact on pepper production in the community. It is in this light that this study was carried out to examine and find out the impacts of variabilities in climatic conditions with respect to the changes of temperature and rainfall on pepper yields in Sabegu.

Research Question

This study was done to address the following research question:

To what extent have climatic factors, particularly temperature and rainfall, changed in the Tolon District in northern Ghana leading to corresponding adverse impacts on pepper production in Sabegu?

Materials and Methods

General Description of the Study Area

Location and Population Size

The study was done at Sabegu in the Tolon District (Figure 1) of the Northern Region of Ghana. Sabegu is made up of 42 households with a population of about 391 people. The District lies between latitudes 9^0 15` and $10^0$ 02` north and longitudes 0^0 53`and $1^0$ 25` west. It shares boundaries to the west with the North Gonja District, Kumbungu District to the north, Sagnarigu District to the east and Central Gonja District to the south (Tolon District Assembly Report, 2015).

Topography and Drainage

In general, the land in the distict is undulating with some dispersed valleys. The district has no well-demarcated highlands. It has some water bodies, the foremost being the White Volta. Amongst the main tributaries of the White Volta are Koraba, Kulabong, Bawa, Winibo and Salo. The key river and its tributaries show dendrite drainage characteristics. In the dry season, a lot of the tributaries get dried up. Furthermore, a number of communities have smaller dams and dug-outs (Tolon District Assembly Report, 2015).

Rainfall and Vegetation

Sabegu is situated in the Guinea savannah ecological zone. The area has a monomodal rainfall type ranging between 900 and 1000 mm per annum. High temperatures are experienced in the greater parts of the year with 36 °C as the maximum in March and April. In the district, mimimum temperature of 15 ^oC is experienced between December and January (Tolon District Assembly Report, 2015). The one farming season is bound by the harmatan season, which commences in December and ends in March. The harmattan season is characterized by dry, hot winds blown across the Sahara Desert from the north-eastern part of the continent and into Ghana giving rise to dry, hot days and cool nights (Oppong-Anane, 2006).

The vegetation is mainly the grassland type with scattered Guinea Savannah woodland, made up of drought-resilient trees including shea (*Vitellaria paradoxa*), acacia (*Acacia longifolia*), baobab (*Adansonia digitata*), dawadawa (*Parkia biglobosa*), neem (*Azadirachta indica*) and mango (*Mangifera indica*). These are trees with economic values and constitute an essential component of the people' source of income. Sabegu is endowed with some natural resources which include land for both farming and housing. The farmers cultivate a wide range of crops including arable, vegetable and medicinal plants. Vegetable crops that are mostly grown in the community include pepper, tomatoes, garden eggs, cabbage, okra, amaranthus and onion. Farming is mostly undertaken by men. Other activities that people are involved in include shea butter processing, petty trading, rice parboiling process, and bicycle fitting work. However, bush fires and other poor farming practices are negatively affecting agricultural productivity in the community. Farmers in Sabegu as in other communities in the Tolon district are predominantly peasant farmers who rely extensively on rainfall for crop cultivation, and this makes it vulnerable to changes in the climate (Tolon District Assembly Report, 2015).

The research was conducted in Sabegu in the Tolon District (Figure 1) of the Northern Region of Ghana. Sabegu consists of 42 households with a population of about 1150 people. The District is located between latitudes 9^0 15` and $10^0$ 02` N and Longitudes 0^0 53`and$1^0$ 25` W. Sabegu is in the Guinea Savannah agro-ecological zone. The zone experiences a unimodal rainfall pattern, with amounts ranging between 900 and 1000 mm per annum. The

temperatures rise during greater parts of the year with the peak being 36 °C in March and April. In the district, lower temperature of 15 °C is experienced between December and January. The main vegetation is grassland, interspersed with Guinea Savannah woodland. Farmers in Sabegu, as in other communities in the Tolon district, are predominantly peasant farmers who rely extensively on rainfall for crop cultivation, and this makes it vulnerable to changes in the climate (Tolon District Assembly Report, 2015).

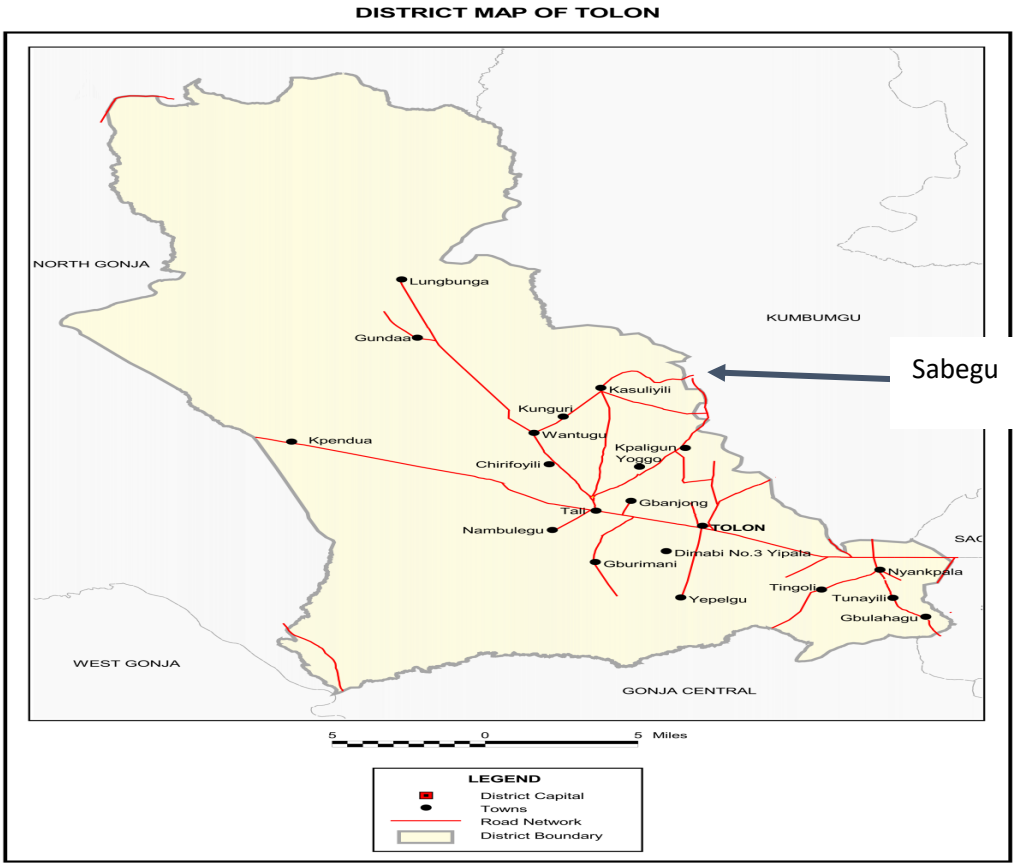

Figure 1: Map of Tolon District showing Sabegu
Source: GSS (2010).

Sample Size and Technique of Data Collection
Forty-one (41) farmers were purposively selected as representative of the total number of pepper farmers in Sabegu for interviews. The interviews were conducted through the administration of semi-structured questionnaires.

Source and Type of Data
Primary and secondary data were gathered during the research. Through the use of semi-structured questionnaires, the primary data were gathered from the farmers, and this included information on how pepper production is influenced by climate change as well as the adaptation measure used to overcome the impact. The farmers interviewed were all small-scale, rainfall-dependent pepper farmers. Secondary information was collected from the internet, journals and other sources. Figures on temperature as well as rainfall for a period of 20 years in the district was collected from the Agro-meteorological Department of Savannah Agricultural Research Institute (SARI).

Method of Data Analysis and Interpretation

Available data on yield of pepper for a period of three years, 2013-2015, were taken from the farmers. Also time-series data on annual temperature and rainfall for the district covering the period of 1995-2015 were collected and analyzed. Both primary and secondary data were subjected tp analysis and the findings were interpreted and presented in the form of tables as frequencies and percentages and figures as charts. The gathered data were subjected to regression analysis using Statistical Package for the Social Sciences (SPSS) and the results were interpreted in simple descriptive statistics in the form of graphs and pie-charts using Microsoft Excel.

Results and Discussion

Trend of Temperature

The study examined the trend in temperature pattern over the period of twenty-one years (1995 – 2015). The findings show that the mean annual temperatures in the Tolon District have been fluctuating (Figure 2). It remained fairly even from 1995 to 2003 and rose to a peak in 2004 (32.8 °C) but declined in the subsequent years up to 2011, after which a further decline and rise were observed. In overall terms, the temperatures recorded for 1995 and 2015 were approximately 28.0 °C and 30.0 °C respectively, indicating that there was a rise in temperature by about 2 °C over the twenty-year study period. A statistical analysis of the trend of temperature over twenty-one years (1995-2015) in the Tolon District (Figure 3) split into 3 time-zone periods (1995-2001, 2002-2008 and 2009-2015) show that there were significant differences *($p < 0.05$)* among the periods, with the periods 2002-2008 and 2009-2015 having differed significantly *($p < 0.05$)* from the 1995 period in terms of temperatures recorded within those periods. Although the periods 2002-2008 and 2009-2015 did not differ significantly *($p > 0.05$)* from each other, general increases in temperature were however recorded from 2002 to 2015 in the district.

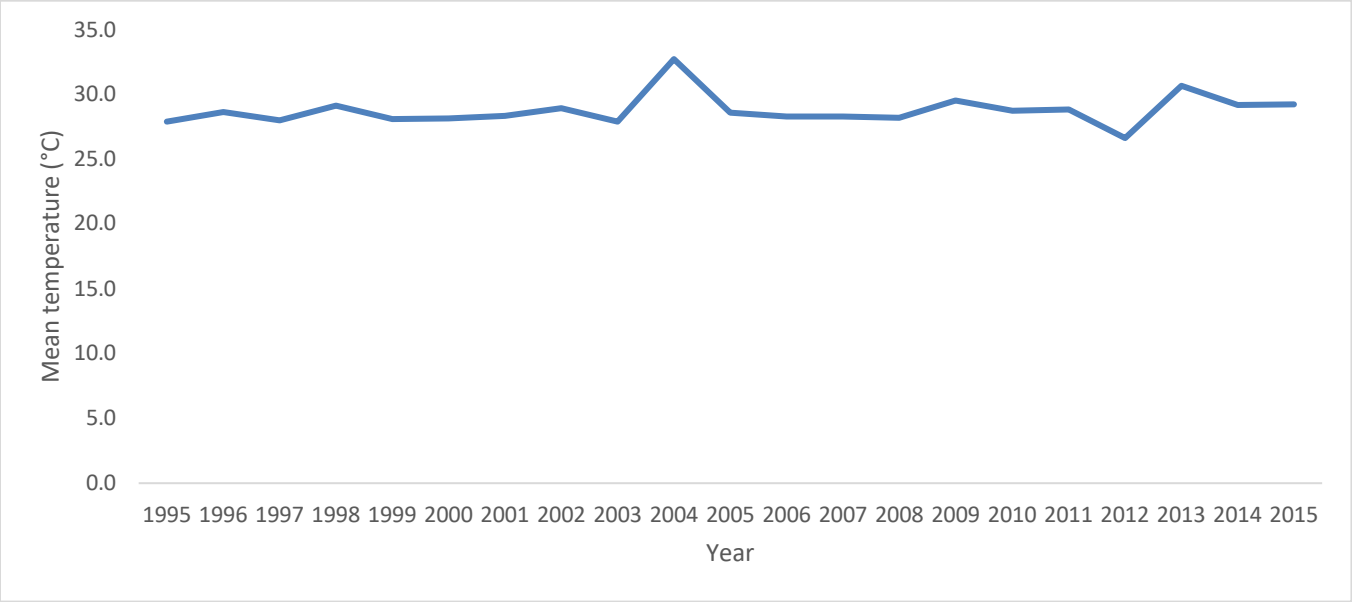

Figure 2: Trend of temperature in the Tolon District from 1995 – 2015

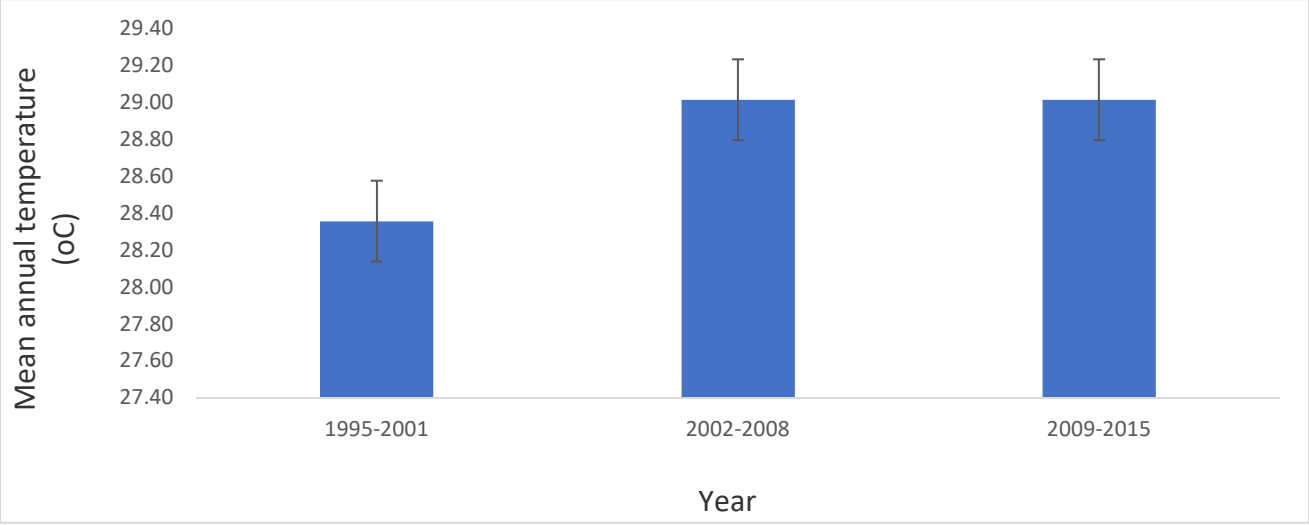

Figure 3: Statistical Analysis of Trend of Temperature in the Tolon District from 1995 – 2015

Datta (2013) stated that in pepper, high temperatures after pollination prevented formation of fruits, signifying that high temperatures affect crop yields. It was realized from the study that pepper yields declined from 5.2 tons ha^{-1} in 2013 to 4.8 tons ha^{-1} 2015 (Figure 4) because the mean temperatures generally increased from 27.9 ºC in 1995 to 29.3 ºC in 2015. Continuous changes in temperature affect crops' development due to environmental stress and environmental stresses are the principal reason for losses in global crop yields, decreasing by more than half the yields of majority of crops (Bajguz and Hayat, 2009).

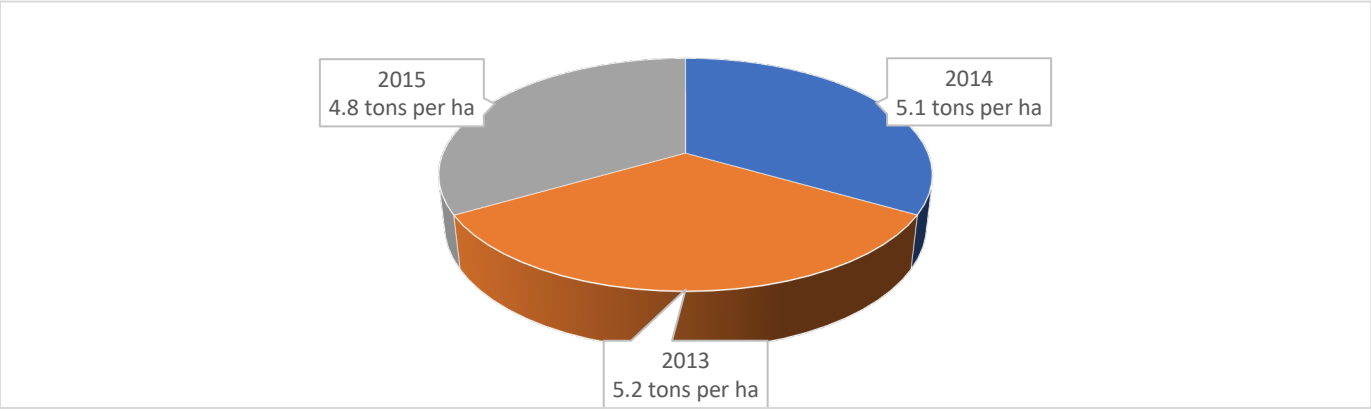

Figure 4: Yield of Pepper in Sabegu between 2013 and 2015

Trend of Rainfall

It was evident from the study that there was a seasonal variation in the rainfall pattern for the 1995–2015 period under study (Figure 5). The study showed that, the lowest mean annual rainfall of 872 mm was recorded in 2005. Highest mean annual rainfall of 1112 mm was recorded in 1999. The amount of rainfall has reduced since that time to 2015 which recorded a mean of 800 mm. On a broader scale however, for the twenty-one-year study period, the volume of rainfall recorded declined from about 1008 mm in 1995 to about 800 mm in 2015, indicating a reduction of approximately 208 mm of rainfall. On statistically analyzing the trend of rainfall in the Tolon District for twenty-one years (1995-2015) and dividing that duration into 3 time-zone periods (1995-

2001, 2002-2008 and 2009-2015), those periods differed significantly ($p < 0.05$) with respect to amounts of rainfall, with the periods 2002-2008 and 2009-2015 being significantly different ($p < 0.05$) from the 1995 period. In overall terms, general reductions in amounts of annual were recorded from 2002 to 2015 in the district, despite the fact that the period 2002-2008 not differ significantly ($p > 0.05$) from the 2009-2015 period.

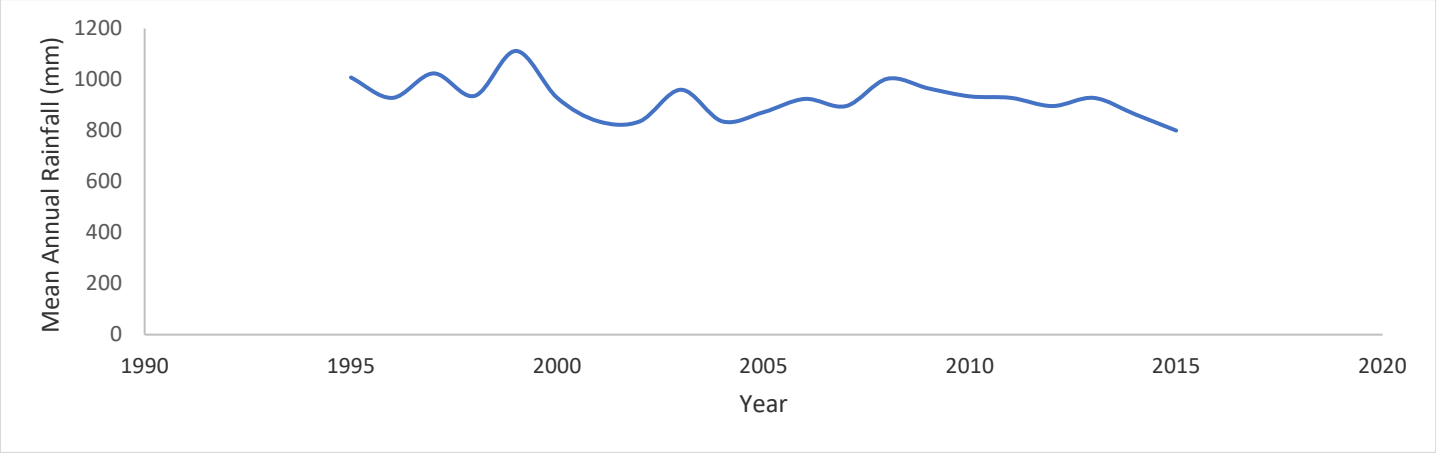

Figure 5: Trend of rainfall in Tolon District from 1995 – 2015

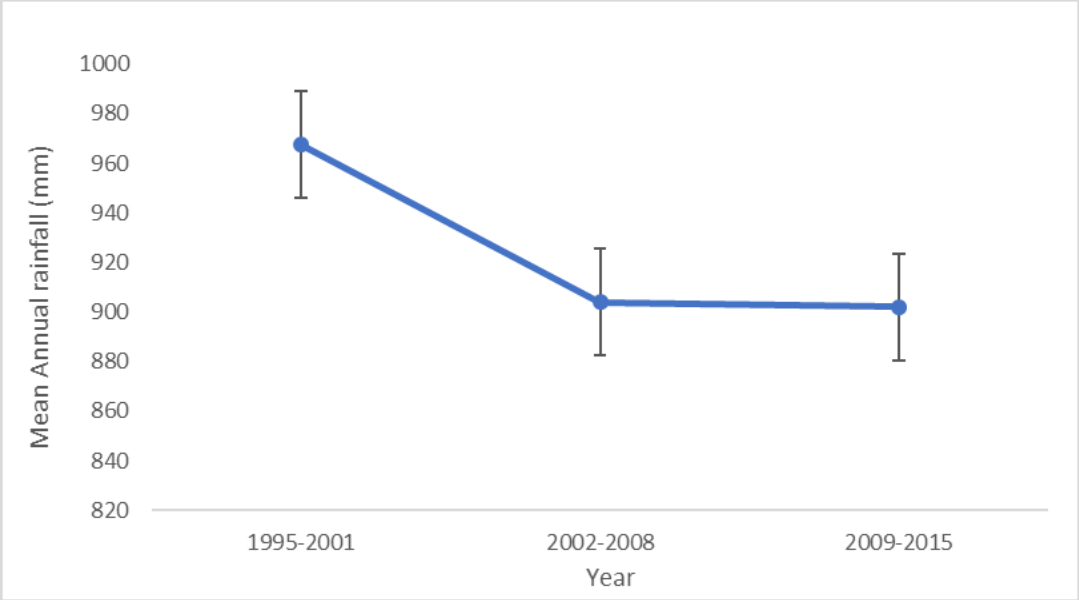

Figure 6: Statistical Analysis of Trend of Rainfall in Tolon District from 1995 – 2015

The amount of rainfall is important for the growth of plants so is its pattern. Water stress has significant effect on plant physiology. Crops of the solanaceae family, where pepper belongs, do not require excessive rainfall, and therefore watering ought to be restricted to crops' minimum requirements, as stated by Savvas *et al*. (2009). However, very low amount of water reduces the vegetative growth and the plants' ability to photosynthesize while prolonged periods of drought may result in wilting and subsequent death of the plant.

Conclusion and Recommendation

The research findings indicate that temperature and rainfall patterns have generally fluctuated over the twenty-year study period resulting in adverse

impacts on pepper production in Sabegu, thereby reducing yields of the crop. In view of the results of this study, farmers ought to be sensitized by the appropriate agencies, including the Ministries of Food and Agriculture, Environment, Science Technology and Innovation, Lands and Forestry and the Environmental Protection Agency on the effects of deforestation and bush burning in order to enable them adopt suitable measures to deal with climate change impacts.

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