Research Article

Impacts of Climate Change and Climate Variability on Cocoa (*Theobroma Cacao*) Yields in Meme Division, South West Region of Cameroon

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ABSTRACT

An assessment of trends of climate change and variability on cocoa yields from 1975 to 2010 in Meme Division aimed at providing a framework for future adaptation strategies was focused on relating cocoa yield with climatic conditions. Rainfall and temperature data were analyzed by fitting regression lines in an attempt to determine their trend during the study period and possible future projections. The purposive sampling technique was used to select ten villages using a criteria based on the proportion of the population involved in cocoa cultivation. Farm selection was based on age, consistency of sizes and management practices in an attempt to keep the factors affecting cocoa yield constant. Data on cocoa yield, flowering, and pod infestation were obtained through semi-structured questionnaire and analyzed using univariate, bivariate and graphical techniques. The results revealed that increased rainfall above 3000mm per annum, decreased cocoa yields by 0.16% per millimeter while increased temperatures of 0.34°C per decade increased cocoa yield. Flowering intensity also varied with seasons and was continuous in some localities, while cocoa black pod infestation increased with rainfall and low temperatures, and vice versa for capsids.

Key words: climate change and variability, cocoa yields, Meme Division, black pod infestation, capsids

Résumé

Une évaluation de la tendance des changement climatique et la variabilité des rendements du cacaoyer de 1975 a 2010 au Departement de Meme a fournir une structure pour les stratégies d'adaptation a été mis au point en lien entre les rendements du cacaoyer et les changements climatiques. Les données de la pluviométrie et de la température ont été analysées par les droites de régression dans le but de ressortir leur tendance pendant la période de l'étude et les projections futures possibles. Dans cet optique, une technique d'échantillonnage a été mise en place pour sélectionner dix villages de la zone d'étude basée sur les critères de proportion de la population s'adonnant a la cacaoculture. Les plantations sélectionnées étaient basées sur leur âge, leur taille et sur les pratiques culturales dans le but de garder constant les facteurs affectant les rendements du cacaoyer. Les données des rendements du cacaoyer, la floraison et l'infestation des cabosses avaient été obtenues a travers un questionnaire semi-structuré. Les analyses des données ont été faites par l'utilisation de la technique mono variable, bi variable et graphique. Les résultats ont révélé que l'augmentation de la pluviométrie au-delà de 3000mm par an, les rendements du cacaoyer décroissent de 0,16%, alors qu'une augmentation de la température de 0,34°C par décade augmenterait les rendements du cacaoyer. L'intensité de la floraison aussi varierait avec les saisons et demeurait continuelle dans certaines localités, pendent que la pourriture brune augmenterait avec la pluviométrie et les faibles températures, et vice versa, de même pour les mirides.

Mots clés : changement climatique et la variabilité, rendements du cacaoyer, Departement de Meme, pourriture brune, mirides.

INTRODUCTION

Background

Cocoa, as presented by the International Cocoa and Coffee Organization, ICCO (2007) and World Cocoa Foundation, WCF (2010), is an important cash crop for developing countries and a key import for processing and consuming countries. It was introduced into Cameroon from Sao Tome and Principe in the Nineteenth Century as stated by Nya (1981) and Opeke (1987). According to Ardener (1996), it was introduced by the German colonial administration in the western coastal areas, including areas around Mount Cameroon, in 1886. Alvenson *et al.*(1999), classified the cacao tree under the family Malvaceae and the genus *Theobroma*. Although, all cultivated cocoas show great variability, Gordon (1976) and later Wood (1991) pointed out the fact that these cocoas can be divided within the species, into three large groups (varieties) based on their different geographical origins: Criollo, Forastero and Trinitario. Wood (1991) further revealed that the Trinitario and Criollo (commonly known as German cocoa) introduced by the Germans are still cultivated with a mixture of hybrid varieties introduced by the Institute of Agricultural Research for Development (IRAD) in Cameroon. Production rate in the South West Region is the highest in the country and accounts significantly for the total production of cocoa, ranking Cameroon the fifth producer of cocoa in the world as recently classified by Mbondji (2012).

In Cameroon as cited by Sonwa *et al.* (2008), cocoa farming is carried out in the South West, Littoral, Centre and South Regions. Official figures show production to have increased from 98,000 to 134,000 tons per annum from 1990 to 2002, and then sharply to 205,000 tons in 2009. As a major perennial cash crop, Losch *et al.* (1990) and later Kazianga and Sander (2002) pointed out that cocoa has been shown to play a vital role in improving the livelihoods of over 400,000 households producing cocoa in Cameroon.

The impacts of climate change and variability are particularly strong in developing countries in the tropics with low levels of crop management technology. In many cases, Challinor *et al.* (2003) showed that they are exposed to high variability in climate. Following Ayoade (2004), daily, seasonal, or annual variations in the values of climatic variables are of greater importance in determining the efficiency of crop growth.

According to Balasimha (2012) temperature is likely to increase up to 2.0°C by 2050 in the cocoa growing regions of Ghana and Ivory Coast. Balasimha (2012) further quantified the impacts of major climatic parameters such as increasing temperature and CO_2 levels in field experimentation by growing the crop in open top chamber (OTC) or in free air carbon dioxide enrichment (FSCE) and free atmospheric temperature elevation (FATE) which have proven to influence cocoa production with more extreme events in their variability, making the cocoa plant more vulnerable. Such control studies however are unsuitable for climate change studies as they do not include changing rainfall patterns and their utilization will require various climate change scenarios in combination with different management parameters for analyzing real impact of climate change under normal conditions.

The Intergovernmental Panel on Climate Change, IPCC (1990) explained that in Cameroon's' rain fed agriculture; climate is the main factor determining crop types and yields. According to Legates et al. (2005) climate is perceived to be changing worldwide and there has been growing concern as to the effects of these changes. The 1970s were characterized by a severe climatic crisis whose effects were negative impacts on cocoa production and in 1983, a second harsh climatic crisis affected Cameroon cited by the Food and Agriculture Organization, FAO (2000). This was evidenced by large fluctuations in temperature and rainfall deficits that also affected production.

In Cameroon according to Fongang (1998), weather records have only been kept from 1926 onwards. According to Ngakfumbe (2001) and Ayonghe (2001) climatic data in Cameroon, though available only for a short period have not been well analyzed and trends in their variations well assessed.

In this paper we attempt to fill the gap of processing climatic data, assessing trends as well as examining the effects of long and short term climatic changes and climate variability on cocoa yields within the study area in an attempt to provide a framework for adaptation strategies in the future.

MATERIALS AND METHODS

Description of the study area

The Meme Division found in the South West Region of Cameroon is located between longitudes 4°37" and 6°35" east of the Greenwich Meridian, and latitudes 9°25" and 10°28" north of the Equator. It falls within the coastal lowland with relief ranging from 200m to 800m above sea level. It is located in the mono-modal semi humid forest agro-ecological zone marked by two distinct seasons; a long rainy season extending from March to November and a short dry season (3 months). The mean annual rainfall varies between 2500mm to 3250mm. The mean monthly temperature is about 25°C. Rainfall seasonality and altitude range characterize the local ecosystem as that of a tropical wet forest life zone and suitable for cocoa cultivation as proposed by Kotto-Same *et al*. (1997). The Division is characterized by mainly sedimentary rocks whose decomposition gives rise to clayey and ferralitic soils.

Data collection

Climatic data computed from daily records obtained from the Institute of Agricultural Research for Development (IRAD) Barombi Kang, Kumba meteorological station comprised mean annual temperatures and total amounts of annual rainfall of the study area for a period of 35 years (1975 to 2010). Semi-structured questionnaires were used to collect both qualitative and quantitative data which comprised general information and age of the farm, the farm management practices, the timing of flowering, incidence of pests (capsids) and diseases (black pod disease) and information on cocoa yields.

A purposive sampling technique described by Patton (1990) was used for the selection of villages, localities and cocoa farmers since not all localities are actively involved in cocoa cultivation. The first criterion was the distance (maximum acceptable distance of 30km) from the village to the weather station (IRAD Kumba / Barombi Kang). The proportion of the population (in every village) involved in cocoa cultivation was also taken into consideration. A total of ten selected cocoa farmers in ten villages within the study area were administered questionnaires. The villages and localities sampled include Banga Bakundu, Barombi Kang, Mbalangi, Ediki, Ikiliwindi, Kake II, Small Ekombe, Kossala (Kumba), Teke and Etam, all of which are important cocoa growing areas within the Division. Only farmers who had maintained the same farm surface areas since creation till the time of data collection and farm management practices (proper timing in clearing, pruning and spraying) throughout the years were considered. This was an attempt to keep all other factors that affect cocoa yields constant. Productivity in kilograms per hectare (kg/ha) was calculated from data on cocoa yields obtained from record books of individual farmers'.

Data analysis and presentation

MS Excel software was used to plot graphs of average annual temperatures and total amounts of annual rainfall were plotted and regression lines fitted to these graphs were used to obtain the general trends of the climatic parameter in question and the equations for each trend line used to compute future projections to 2015 and 2020 as described by Barry and Chorley (1992). Qualitative data about the cocoa plant (time of flowering, pests and diseases) were analyzed using descriptive statistical tools such as frequency counts, averages and percentages. Data on mean annual yields of cocoa were converted from field measurements (bags) to universal units (kilograms) to ease and standardize analysis. The sizes of cocoa farms given in "poles" were converted to hectares (ha) using the following formula: $y = ab/4$……..(1) where a is the number of poles of the length, b is the number of poles of the other side and y the number of hectares.

Univariate and multivariate statistical techniques (correlations-Pearson's correlation coefficient, t-test) were used to determine relationships between climatic variables (rainfall, temperature) and cocoa yields.

RESULTS

Variation in rainfall and temperature patterns

A graphical presentation of the total annual rainfall is shown in Figure 1a and average annual temperature in Figure 1b. The highest annual rainfall was evident in 2001 (3491.5mm) and 2008 (3133.1mm) the lowest value in 2004 (1031.5mm). When projected to 2015 and 2020 by use of the equation of the regression line (y = 0.566x + 1075), the corresponding total annual rainfall will be 2215.5mm in 2015 and 2218.3mm in 2020 respectively. The plot shows random fluctuations from year to year while the use of the regression line has revealed an overall increasing trend. The low total annual rainfall in 2004 could be attributed to the high mean temperatures (25.1°C) recorded that same year.

Highest temperatures were recorded in 2007 (26.0°C), 1981 (25.5°C) and 2004 (25.2°C). These increased temperatures could be attributed to the consequences of global warming. The lowest temperatures were evident in 1999, 2000 and 2001 with 22.9°C recorded each year (Figure 1b). The low temperatures in 2001 could possibly be as a result of the very high total annual rainfall of 3491.5mm recorded that year. Graphical plots of mean annual temperatures showed an overall increasing trend as shown by the positive slope of the regression line. The net change in temperatures during the entire period was 1.3°C giving an approximate increase of 0.34°C per decade. Corresponding temperatures computed by use of the equation of the regression line (y = 007x + 10.21) for 2015 and 2020 were 24.31°C and 24.35°C respectively.

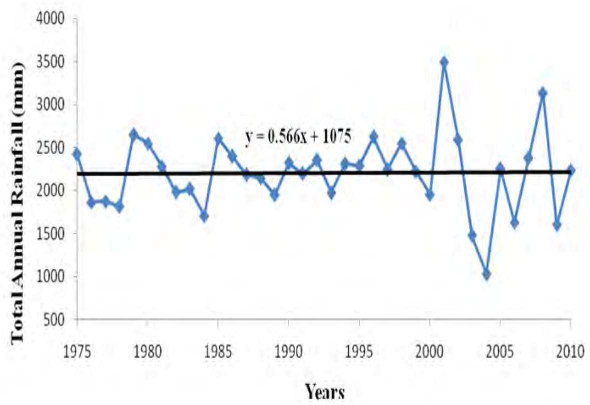


Figure 1a: A plot of total annual rainfall (mm) from 1975 to 2010 with regression line

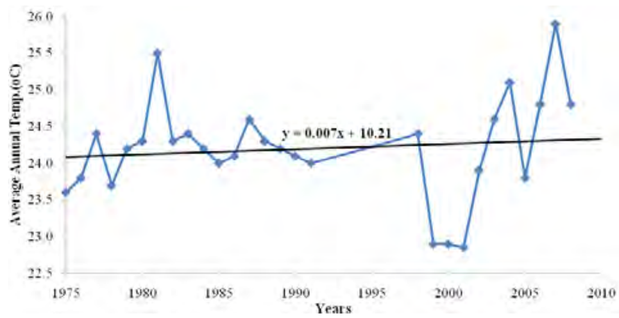


Figure 1b: A plot of average annual temperature (oC) from 1975 to 2010 with regression line fitted

Variations in annual cocoa productivity

A summary of cocoa productivity for all ten villages revealed that productivity values within the study area ranged from 46.5 kg/ha to 648 kg/ha (Figure 2). Cocoa yields varied in the different villages with time with an exception experienced in 2006. Although the best yields were registered in Etam (648 kg/ha), lowest yields were recorded in four other villages (Mbalangi, Ikiliwindi, Kake II and Small Ekombe) in the same year. The low variations in yields could have been as a result of a drop in total annual rainfall, its distribution throughout the year and other factors such as age of the farms and soil types and fertility. A tabular presentation of the variation in productivity in different ranges (table 1) gives a clearer picture with 15% of the farms producing less than 200kg/ha and a greater proportion (40%) having productivity ranging between 342kg/ha and 482kg/ha thus indicating that yields within the study area are generally low.

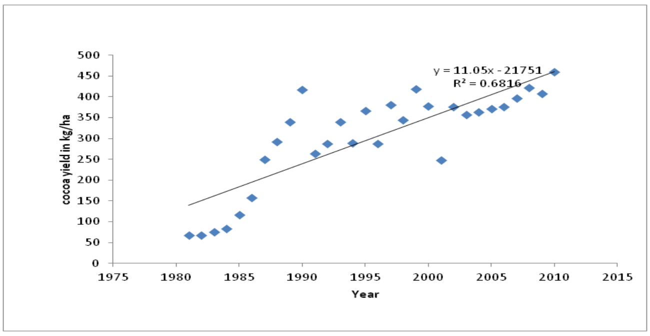


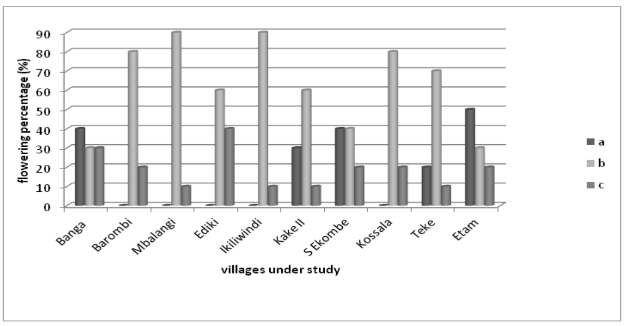
Figure 2: Correlation between cocoa productivity from 1981 to 2010 with regression line fitted on the plot.

Table 1: Range of cocoa productivity with locations within Meme Division

Productivity range (kg/ha)		60 – 200	201 – 341	342 – 482	483 – 623	624 –764	TOTAL
Villages	Banga Bakundu	6	10	4	-	-	20
	Barombi Kang	1	2	3	-	-	6
	Mbalangi	-	2	2	1	-	5
	Ediki	-	2	4	-	-	6
	Ikiliwindi	-	-	1	3	2	6
	Kake II	-	2	3	-	-	5
	Small Ekombe	-	1	3	1	-	5
	Kossala	6	3	11	10	-	30
	Teke	2	-	7	1	-	10
	Etam	-	-	3	4	1	8
Percentage (%) of farmers in range		15%	22%	40%	20%	3%	100

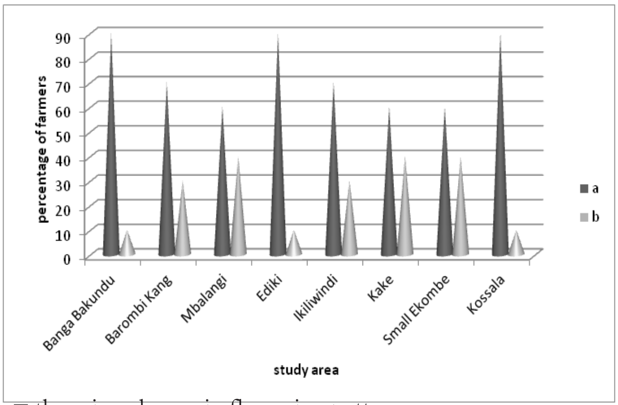
Variations in cocoa flowering periods

Sixty three per cent of the farmers attested that flowering intensity was greatest between March and April, 18% indicated between January and February and 19% between May and June (Figure 3). However, it was observed that periods of greatest flowering intensity vary in the villages sampled. Flowering intensity was highest in Banga Bakundu and Etam in the months of January and February with 40% and 50% respectively. Small Ekombe stood out such that flowering intensity was greatest between the months of January to April. The highest changes in flowering patterns were recorded in Banga Bakundu, Kossala and Ediki with 90% of respondents affirming to the fact that there was a change in flowering pattern (Figure 4a). A total of 66% of the farmers surveyed indicated that flowering occurs throughout the year (Figure 4b) with the villages showing the highest frequency of continuous flowering being Banga Bakundu (90%), Ediki (80%), Kosala, Teke and Etam (70% each). These differences could probably be as a result of variations in the varieties of cocoa planting materials used by farmers in the different villages and variability in the start of the rainy season.



Legend: a= January to February; b= March to April; c= May to June

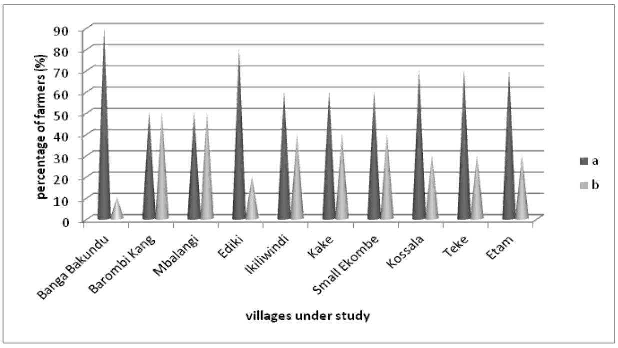
Figure 3: Peak cocoa flowering periods in different localities



a= there is a change in flowering pattern

b= there is no change in the flowering pattern

Figure 4a: Percentage of respondents on the variability of cocoa flowering within the year



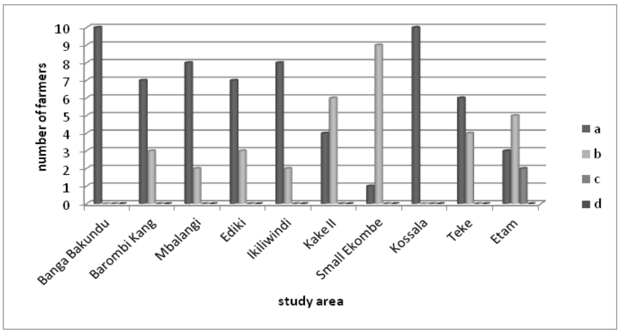
Legend: a= flowering is continuous throughout the year

b= flowering is not continuous throughout the year.

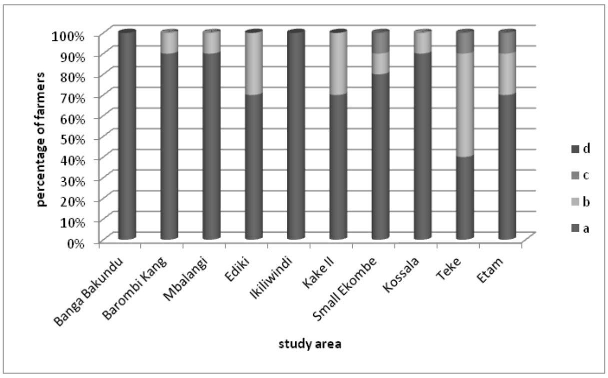
Figure 4b: Variations in the percentage of respondents on the continuity of cocoa flowering within the year

Cocoa pod infestations

Figure 5a reveals that 64% of the farmers indicated very little attacks (less than 25%) of cocoa pods by black pod disease in their farms while 2% of the farmers indicated high rates of attack (51-75%). With regards to capsids attack, 80% of the farmers indicated very little attacks (less than 25%) while 17% of the farmers indicated high rates of attack (50%) as seen in Figure 5b. This apparently reduced degree of black pod disease and capsids infestations which are based on the limits presented in the questionnaire could be as a result of the fact that the farmers respect good farm management practices (timely spraying, pruning and clearing).



Legend: a= <25%; b= 50%; c= 51-75%; d= >75%
Figure 5a: proportion of cocoa pods attacked by black pod disease



Legend: a= <25%; b= 50%; c= 51-75%; d= >75%
Figure 5b: proportion of cocoa pods attacked by capsids

Correlations between climatic variables and cocoa yields

Pearson's correlation coefficient used to find out relationships between climatic variables and cocoa yields showed a weak negative (inverse) correlation between rainfall and temperature (-0.05). As rainfall increased the temperatures decreased and vice versa. Rainfall showed a very weak negative correlation with cocoa yields (-0.012). Similarly as rainfall increased above a threshold value of 3000mm per annum, cocoa yields tend to decrease by 0.16% per additional millimeter (table 2).

Table 2: Pearson's correlation matrix of rainfall, temperature and cocoa yields

	Rainfall (mm)	**Temperature (°C)**	**Productivity (kg/ha)**
Rainfall (mm)	1		
Temperature (°C)	-0.05	1	
Productivity	-0.012*	0.12	1

Temperature demonstrated a weak positive correlation with cocoa yields (0.12) implying that as temperature increased, cocoa productivity also increased. The bi-variate plot (XY scatter plots) showed correlations between rainfall, temperature and productivity with lines of best fit (Figures 6a, b and c). Figure 6a showed a high degree of scattering, Figure 6b no correlation (R2 = 0), while Figure 6c shows some degree of clustering indicating little correlation (R2 value is positive).

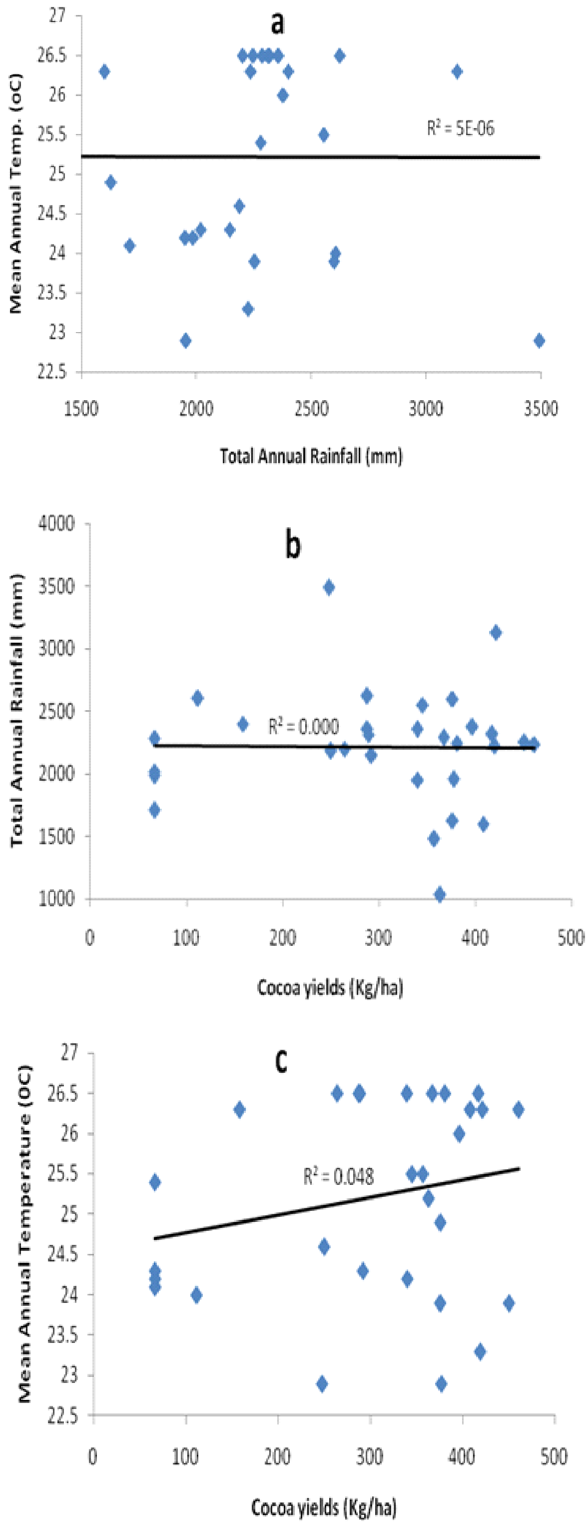


Figure 6: XY scatter plots of a) rainfall and temperature, b) rainfall and cocoa yields and c) temperature and cocoa yields

T-test analysis of the effects of rainfall and temperature on cocoa yields

The t-test revealed that at a probability level (α) of 0.05 there was a significant difference between rainfall and temperature. There was also a significant difference between rainfall and cocoa yields as shown in table 3. This implies that increased rainfall significantly favors cocoa yields. However no significant difference was revealed between temperature and cocoa yields.

Table 3: T-test on rainfall, temperature and cocoa yield

Variables	T calculated (t calc)	T expected (t exp)	Results
Rainfall-Temp	21.9	1.72	t calc. > t exp.
Rainfall-cocoa yields	21.7	1.72	t calc. > t exp.
Temperature-cocoa yields	-10.6	<1	t exp. > t calc.

Where α= 0.05 (that is, at 95% confidence interval)

DISCUSSION

Rainfall and temperature trends

The trend in rainfall and temperature patterns revealed an overall increase over the years shown by the positive slopes of the regression lines. The observed increasing rainfall trends in the study area falls in line with overall increasing rainfall patterns in the coastal areas of Cameroon described by Ayonghe (2001). The observed lowest rainfall registered in 2004 (1031.5mm) could possibly be as a result of the concurrent increase in temperatures (25.2°C).

Following the IPCC (1992), current trends in climate change scenarios reveal that global temperatures are on the increase with estimates showing that global surface temperature will increase between 1.5°C and 4.5°C by 2010 and 2050 respectively. But according to Ayonghe (2001), temperatures over Cameroon have been on the increase since 1930, the net rate of increase had been 0.95°C between 1930 and 1995. The 0.34°C fast rate of increase in temperature per decade from 1975 to 2010 is quite significant falling in line with the increasing trends in Cameroon in conformity with the global trend as projected by the IPCC (1992).

Effects of short term extreme climatic variables on the cocoa plant

Field investigations and results of farmers' opinions suggested that patterns of flowering in cocoa have changed over the years. Alvim (1966) explained that such patterns in flowering behavior are attributed to changes in rainfall and temperature patterns as flowering initiation and intensity in cocoa is greatly determined by changes in rainfall patterns in particular described by Mohr and Schopfer (1994) and later by Omolaja *et al.* (2009).

Results on the incidence of black pod disease reveal that a small proportion of farms sampled are highly attacked by black pod disease. These results which show a decrease in the incidence of insect pests and diseases in cocoa farms in the study area further confirms results of other studies by Nyasse (1997) as well as Bakala and Kone (1998) which reported 80% loss in cocoa yields as a result of the black pod disease and capsids. Although the study revealed overall increasing trends in productivity, it is considered low by Dormon *et al.* (2004) who identified it as one of the major challenges in cocoa cultivation in Ghana.

Influence of climate change and variability on cocoa yields

It is generally expected that productivity should increase with time provided all other factors that determine yield are kept constant but fluctuations or drops have been recorded in some years. These fluctuations therefore can be blamed on long and short term changes in climatic variables of temperature and rainfall. Decrease in productivity was recorded in years with high rainfall (1996, 1998 and 2001). This can be attributed to the fact that, high rainfall, increase in number of rainy days coupled with low temperatures increase humidity providing a favorable environment for fungal disease (black pod disease). This has a negative effect on cocoa yields. Increased temperatures provide favorable environment for breeding of insect pests and this has proven to have negative effects on cocoa yields as the insects destroy the cocoa pods as described by Nyasse (1997).

Results of correlations have shown a negative correlation between rainfall and cocoa yields. This implies that a minimum quantity of rainfall is needed for good performance of cocoa as explained by Aigbekaen (2009); high rainfall is detrimental to some metabolic processes that contribute to pod development. According Kayode (2010), temperature has no significant effects on cocoa yields although Lawal and Emaku (2007) and, Ajewole and Sadiq (2010) indicated some inter relationship between increase in temperature and cocoa yields since temperature influences photosynthesis.

CONCLUSION

The rainfall and temperature patterns in the study area have been changing with an alarming net increase in temperature of 0.34^{o}C per decade. Both short and long term changes in climatic variables (rainfall and temperature) have effects on the cocoa plant. Increased temperatures increased cocoa yields while increased rainfall above 3000mm per year reduced cocoa yields. Flowering pattern changed over the years with a continuous flowering noticed in some localities.

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