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The Relationship Between Annual Rainfall Totals, Rainfall Onsets and Cocoa Yields in Ashanti Region of Ghana: A Reality or Farce?

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Abstract
Cocoa production in Ghana is basically rain fed and this makes it vulnerable to climate change and variability. This paper is part of an on-going research, which is investigating how changes in the climatic conditions in Ghana are affecting production levels of the cocoa industry. The study uses basically secondary data from the Ghana Cocoa Marketing Company and the Ghana Meteorological Service Weather stations at the Kwame Nkrumah University of Science and Technology, Kumasi and the Kumasi Airport between 1970 and 2010. Findings from the study reveal a decline in cocoa production of about 100,000 metric tonnes between 1970 and 1984 in the study region and increasing trend of rainfall totals. Notwithstanding, a direct correlation between rainfall totals and rainfall onsets; and cocoa yields could not be established. However, the study found a highly significant effect of climate variability in rainfall onset and annual rainfall totals on cocoa yield (p-value 0.01). The study thus concludes that climatic change and variability have influence on Ghana's cocoa sector which calls for effective mitigation measures.
Keywords: cocoa production, climate change and variability

1. Introduction

Among the paramount threats to the existence of humankind across the globe in the 21st century is climate change and variability (IPCC 2007). The impact of climate change in all regions of the world has become a topical issue amongst climate science experts and concerned individuals and organisations. This scourge has been of concern to world leaders in most global warming conferences, resulting in treaties and charters being signed by these leaders, yet the situation precariously hangs in the balance. Generally, climate change is attributed to natural internal processes, external forces, and persistent anthropogenic changes in the composition of the atmosphere or in land (IPCC 2011). Presently, climate change is ascribed to the increasing carbon dioxide emissions into the atmosphere as a result of tremendous impact of anthropogenic activities. According to the IPCC (2014), more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in GHG concentrations and other anthropogenic factors.

Studies have shown that the agricultural sector will be among the hardest hit by climate change and variability compared to other sectors (Thornton et al. 2011; Ericksen et al. 2011, Lobell et al. 2008). This is because crop production responds to changes in annual mean temperature and precipitation; changes in the weather and a combination of changes to the mean and its variability (IPCC 2001). The changes in these climate variables affect soil moisture, soil fertility and also increase crop vulnerability to infection, pest infestations and choking of weeds, which reduce crop productivity (Schlenker and Lobell 2010; Stanturf et al. 2011).

A study by McSweeney et al. cited in Stanturf et al. (2011) shows an overall countrywide reduction in rainfall by an average of 2.3mm monthly per decade between the period of 1960 to 2006.The rainfall distribution in semi-arid regions of Africa was also found to have been low and highly variable spatially and inter temporal (Amikuzuna and Donkor 2012). In Ghana, the annual rainfall was found to be highly variable on inter-annual and inter-decadal timescale (Amikuuzuna and Donkor 2012).

The changes in the climatic variables of rainfall and temperature have effects on the onset and length of agricultural growing seasons. Studies by Thornton et al. (2011) has projected changes in length of the growing period for Africa in the 2090s. The authors showed that a large proportion of the cropping and rangeland area of sub-Saharan Africa is projected to experience a decrease in growing season length. The authors also projected that with the exception of Central Africa, there is the probability of increased season failure for all of sub-Saharan Africa (Thornton et al. 2011).

The economy of Ghana is highly vulnerable to climate change and there are clear signs of the direct manifestations of climate change in the country as indicated by the Ministry of Environment, Science, Technology and Innovation (MESTI) (2013). Notwithstanding, the implications of climate change and variability on cocoa (major cash crop in Ghana) yields has not been fully explored. There is gap in knowledge concerning the influence of rainfall total and onset periods on Ghana's cocoa yields. To offer a better understanding of this relationship and to recommend appropriate mitigation measures, a critical look at the annual cocoa yields, annual rainfall totals and annual rainfall onsets periods in the Ashanti region of Ghana between 1970 and 2010 was examined.

2. Profile of Study Area

The Ashanti Region lies in the southern half of Ghana, and occupies 24,389 sq. km. (10.2%) of the total land area of the country (Figure 1). The region lies in the forest zone of Ghana, and it is the third largest region after the Northern and Brong Ahafo regions, respectively. It shares boundaries with the Western, Central, Eastern and Brong Ahafo regions. The region has an average annual rainfall of 1,270 mm (Ghana Statistical Service 2013). The rainfall of the region is strongly controlled by the West African Monsoon (WAM) and convective activities due to the movements of the Inter-Tropical Discontinuity (ITD). The WAM is primarily driven by energy and temperature gradients between the Gulf of Guinea and the Sahara (Amekudzi et al. 2015). The rainfall onset of this region usually occurs around the second to third dekad in March with maximum rains recorded in June. The minor season which is relatively short starts from first to second dekad of September and retreat in the second to third dekad of November (Amekudzi et. al. 2015 and Manazanas et al. 2014). The periods December to March and mid-August to mid-September are relatively dry. The average daily temperature is about 27^{o} C (Ghana Statistical Service 2013).

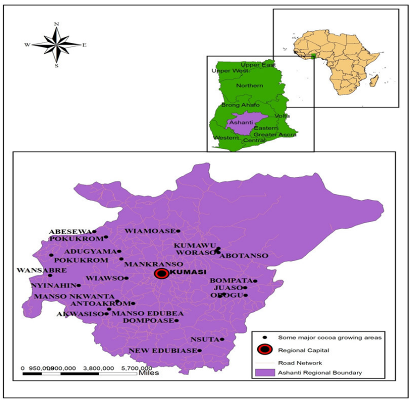

Figure 1. Map of the study area

3. Methods

The study relied principally on secondary data cocoa yields and climate data gathered from the Ashanti Region of Ghana (Figure 1) covering a period of 40 years (1970-2010). Daily rainfall data covering 1970 to 2010, over Kumasi and its adjoining region were acquired from the Ghana Meteorological Agency. A quality check was performed on the datasets to filter out erroneous records. Afterwards, the annual rainfall totals were computed to analyse the annual variability of rainfall in the study area. Furthermore, the rainfall anomalies were computed using equation 1:

$$zi = (Xi- \mu) / \sigma \quad , \qquad (1)$$

where σ is the standard deviation, μ is the mean of the rainfall records (X) and z is the standardized anomaly.

The cocoa yields were equally standardized with the above equation. By this approach, the zero mark is the mean and ($-1 \leq z \leq 1$) is the normal range. Any anomaly value above 1 is termed 'above-normal' and points below termed 'below-normal'. This allowed an easy identification of extreme years with regards to rainfall and cocoa yield.

4. Results and Discussions

4.1 Annual Rainfall Totals

As shown in Figure 2, the annual rainfall totals were normalized for identification of extreme rainfall events. Normal rainfalls lie between the -1 and 1 range. The years 1971, 1973, 1977, 1982, 1983 and 2004 were observed to be dry years, with 1971 and 1983 being the driest. Rainfall totals within these years were at least a σ (1 standard deviation) less than the climatologically mean rainfall for the area. On the contrary, 1979, 1985, 1988, 2000, 2002, 2007 and 2009 were observed to be wet years, with 2007 classified as an extremely wet year ($z > +2\sigma$). Generally, there was an increasing trend in the annual rainfall totals, considering the last half of the period recorded most positive anomalies.

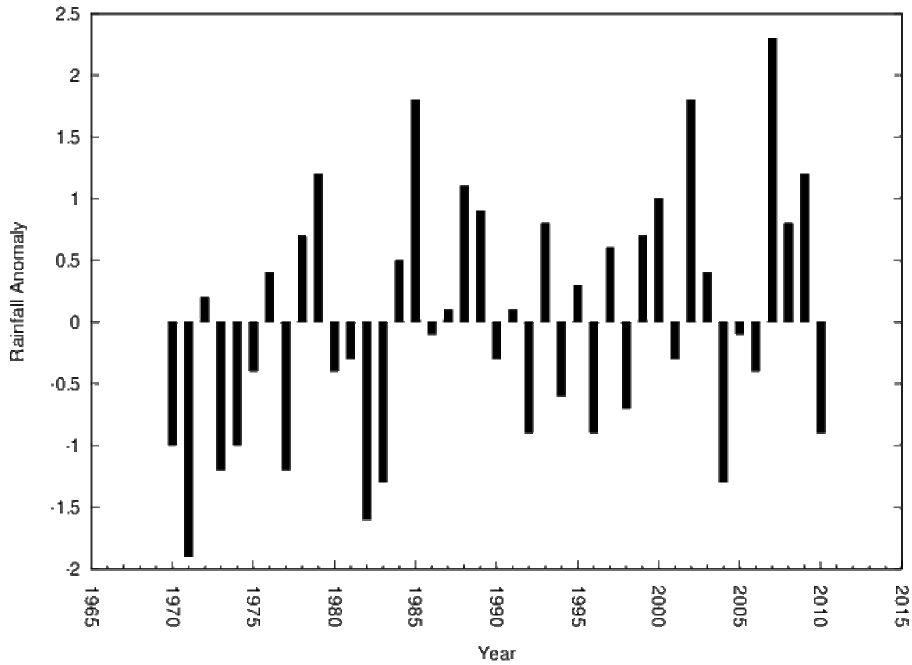

Figure 2. Annual Rainfall Anomaly

4.2 Rainfall Onset Periods

Late onsets of rain were recorded between 1970 and 1975 (Figure 3). There is a likelihood of these late onsets having an impact on the low rainfall anomalies that were observed. This does not reflect however on the yield of cocoa within those periods. There is the tendency that the high yields were due to high rainfall totals in the early years, and also other measures put in place by the farmers which includes but are not limited to good farm management practices (spraying at the appropriate time, fertilizer application, etc.) and supervision in cocoa bean mobilization. In subsequent years, despite the early onsets of rain, cocoa yields were found to dip. These dips are likely attributable to other factors such as bush fires, poor management, cocoa smuggling and bad soil management practices, among others. These, however, were not quantified in this study. On the whole, the relationship between the rainfall onsets, anomalies and cocoa yields need further statistical tests for confirmation. Hence, the pairwise T-test at 99% confidence level was employed, with a null hypothesis that “Rainfall has no impact on cocoa yields” and an alternative hypothesis, “Rainfall has a significant impact on cocoa yield”. For both annual rainfall totals and rainfall onsets, at 99% confidence level, significant trends (p-value <0.01) were observed. Thus, it can be concluded that the variabilities in rainfall onsets and annual rainfall totals have significant impacts on cocoa yields.

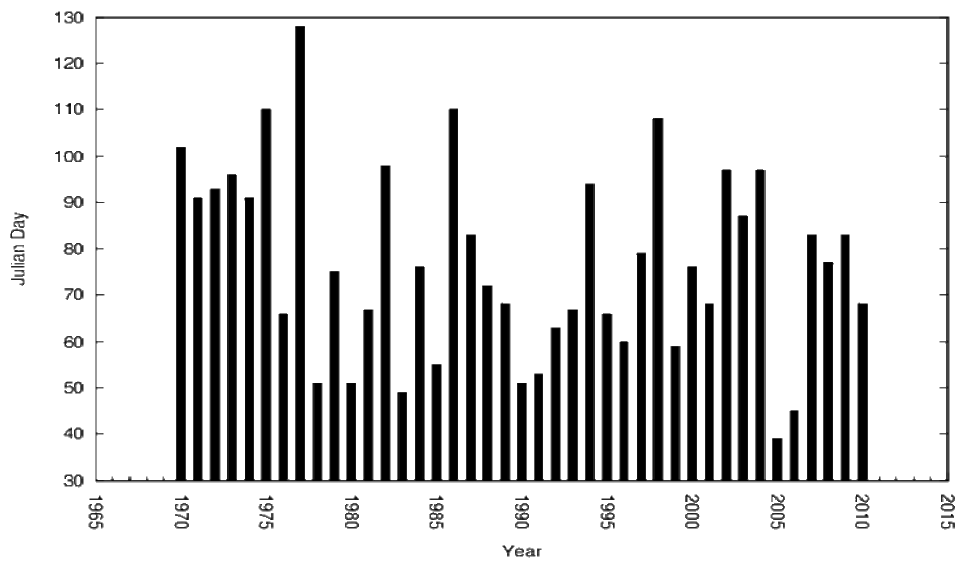

Figure 3. Rainfall Onset Days

4.3 Annual Cocoa Yield

As shown in Figure 4, the first half (pre-1985) showed a decline in cocoa yield, with a dip of approximately 100,000 tonnes recorded over the period. However, cocoa yield increased from 1986 to 2010, with an estimated rise of 80 000 tons over the period. By normal inspection, a direct correlation was difficult to establish between the rainfall anomalies and the annual cocoa yields. Similarly, using the annual rainfall totals, a direct correlation could not be established. As discussed in Amekudzi et al. (2015), there is the possibility that cocoa yields are affected primarily by the length of the growing season and not the annual rainfall total. The major determinant of the length of the growing season was similarly identified by the author as the rainfall onsets, considering the cessation dates rarely varied.

5. Conclusion

The study explored the relationship between rainfall totals and rainfall onsets; and cocoa yields over four decades in the Ashanti of Ghana. A highly significant effect of variability in rainfall onset and annual rainfall totals on cocoa yield was observed although a direct correlation could not be established between climate changes in rainfall regime and cocoa yields. The study thus concludes that there is a correlation between variability of rainfall total and rainfall onsets; and cocoa yields in the Ashanti region of Ghana, thus the reality of the influence of climate variability in Ghana's cocoa sector and the need to implement mitigation measures.

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