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Research Article

# Seasonal Rainfall Variability and Arable Farming within the Dry Equatorial: Evidence from the Effutu Municipality

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**Abstract:** Over the past three decades, one of the major problems that confront developing economies in Africa is the impact of climate variability on agricultural development. In the face of seasonal rainfall variation and the rain-fed nature of farming, agriculture, which is the main source of livelihood for most communities in Ghana, is threatened. The study sought to ascertain the impact of seasonal rainfall variation on arable farming within the Dry Equatorial climate of Ghana, focusing on evidence from the Effutu Municipality. Using coefficient of variation (CV) and the Precipitation Concentration Index (PCI) models, rainfall data spanning for twenty-three years obtained from the Ghana Meteorological Authority were analysed for interseasonal and interannual patterns and variability. The Pearson moment correlation coefficient was used to induce a statistical index to establish the relationship between rainfall distribution and crop yield, particularly for rice production. The findings of the study revealed a high coefficient of variation for both the major and minor rainfall seasons for the past two decades with a corresponding relatively high PCI for the period. This suggests high variability in rainfall patterns in the two seasons over the past twenty years with detection of a general decline in rainfall amounts. A moderate positive P-value for rainfall and crop yield indicates that rice production output is dependent on rainfall patterns within the Effutu Municipality. High rainfall amounts were associated with more rice outputs and vice versa. The study recommends on-farm adaptive practices such as mulching, use of drought-resistant varieties, and government-supported irrigated farming.

***Keywords*:** seasonal rainfall variation, crop yield, Dry Equatorial, Effutu, Ghana

## 1. Introduction

Despite recent effort to migrate the economy to an industry and service sectors-led, agriculture remains fundamental and plays a significant role in Ghana's development [1]. The sector is said to generate approximately 30 per cent of the country's Gross Domestic Product (GDP) to date and provides employment to approximately 50 per cent of the population [1]. A study conducted in Ghana shows that the agricultural sector has the potential to grow at rates as high as six per cent [2], but the issue of climate change and variability could potentially inhibit such progress in the long run, knowing that the kind of agricultural practices carried out in Ghana is particularly vulnerable to this ongoing phenomenon. According to Yaro [3], what makes Ghana's agriculture vulnerable to climate change is


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the sector's overwhelming dependence on rainfall particularly in the country's semi-arid regions. Other underlying problems including pests and diseases coupled with overdependence on crops susceptible to climatic variation, affect the agriculture sector adversely [4].

Poor communities in most developing countries mainly depend on climate-sensitive activities including agriculture for their livelihood, thus, becoming particularly vulnerable to seasonal variations in rainfall [5]. Recent studies indicate that nearly three out of every four people living in rural Africa and other developing countries depend on agriculture in one way or the other [6]. Other reports by African Development Bank [7] and Nelson, Rosegrant, and Koo [8] also estimated that climate change is likely to cause a direct reduction in real household consumption by 5-10% (2050) and a reduction in real gross domestic production by 1.9-7.2% in Ghana. For instance, Ndamani and Watanabe [9] reported that seasonal rainfall variability affects the production of traditional crops, increases the incidence of crop diseases, and causes drastic reductions in the fertility of the soil. In addition to this, an analysis of rainfall conditions in West Africa by Nicholson [10] and Toulmin and Guèye [11] indicates a long-term change in rainfall pattern within the semiarid and sub-humid zones. The mean number of rainy days has significantly reduced throughout the different seasons in West Africa [9].

The impact of rainfall on crop production has been assessed differently by various authors. Among these methods include intraseasonal, interseasonal, and annual rainfall assessment [12]. Owusu and Waylen [13] also employed intraseasonal and interannual variability methods to monitor rainfall patterns in rainy seasons in dry areas of Africa to examine the potential threat of rainfall variability to food security. The number of years of rainfall record that is needed to notice any significant trends in rainfall in arid and semiarid regions is quite controversial. However, evidence reported by Bewket [14] and Logah, Obuobie, Ofori, & Kankam-Yeboah [15] show an undesirable impact of change in seasonal or annual rainfall patterns on cereals production. Also, it has been reported in other parts of the world that climate variability or change has been ascribed to changes in production or will be accountable for future change in production dynamics [16]. Bewket [14] further reported short rainy seasons (March-May) and much more variable rainfall periods between June and September.

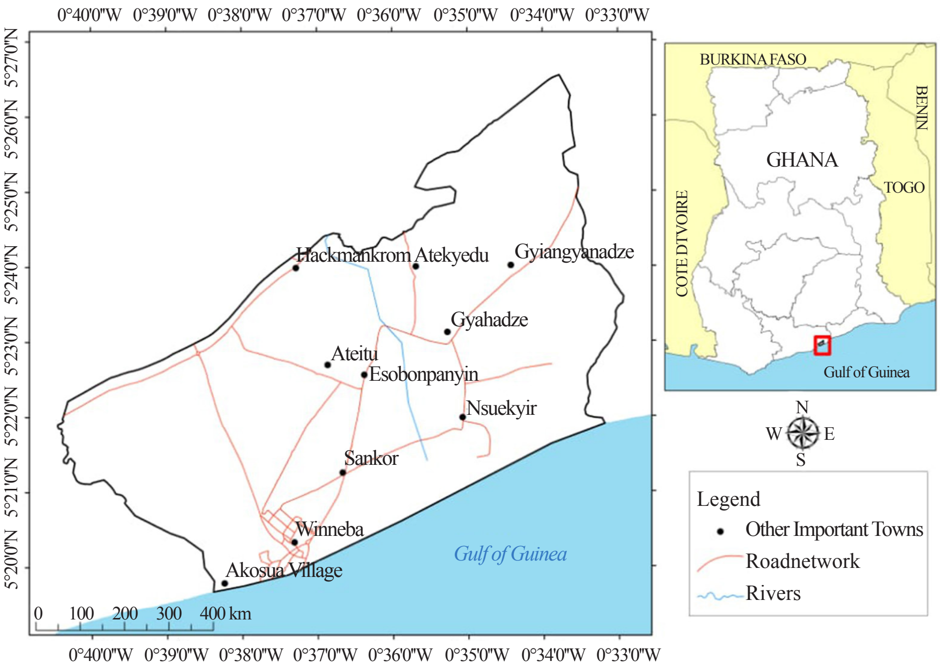
A critical examination of the little literature available on the issue of assessment of rainfall and crop production shows the adaption of different models. These models include computable general or partial equilibrium models, production functions, and Ricardian-type statistical or process-based models, which are often adapted and used in analysing the impact of changes in precipitation on agricultural production [17]. Although these models, especially, Ricardian or cross-sectional approach is used to establish a correlation between how potentially viable a particular land is and the existing agroclimatic conditions, the researchers adapted the coefficient of variation (CV) and precipitation concentration index (PCI) to analyse the interannual and interseasonal rainfall variability. Similar studies conducted by Kabubo-Mariara and Karanja [18], Amikuzuno and Donkoh [17], and Mendelsohn, Nordhaus, and Shaw [19] made use of the CV and PCI. In view of this, the CV and PCI models were adopted for this study. Amikuzuno and Donkoh [17] argue that the PCI has an inherent ability to describe the nature of rainfall distribution. The PCI is used to determine whether rainfall is evenly distributed throughout a year or concentrated in certain months of the year. Further, the Pearson product-moment correlation coefficient was used to generate statistical indices that detect the kind of relationship between two variables whiles indicating the level of significance of such a relationship [20].

The Effutu Municipality lies within the Dry Equatorial climatic region of Ghana, the driest area in Ghana with an annual rainfall amount of about 750 to 850 mm. Notwithstanding the low rainfall values, it has two rainfall seasons occurring from May to June and September and October. The rainy season is followed by a long dry season from November to April. Temperatures are high in the hottest month, about 30°C and about 26°C in August [21]. Given these attributes of the climatic zone, the presence of seasonal rainfall variability exacerbates the problems faced by farmers in the area. More recent statistical evidence shows that interannual variability has increased within the major and minor rainy seasons, while the minor rainy seasons have become much drier and shorter. Crops include rice, maize, tomatoes, green pepper, and cabbage among others are grown in the Effutu Municipality particularly in towns including Winneba and Atekyedo. This study analyses the variability in local rainfall data, examined the interseasonal (main and minor) rainfall distribution trends, and determined the pattern and strength of correlation with crop yield in Effutu Municipality to serve as a basic document for policy discussions on agricultural production and adaptation strategies for the area in the face of the changing climate [21].

## 2. Materials and methods

### 2.1 *Study area*

Effutu lies between latitudes 5°16' and 20.18" N and longitudes 0°32' and 48.32" W of the eastern part of Central Region [20]. The Municipality lies between the Gomoa East District to western, northern and eastern boundaries. On the southern flank is the Gulf of Guinea and its capital is Winneba [20]. The towns selected for the study included Atekyedo and Winneba. These towns were chosen because of the extensive farming carried out there. It covers a total land area of 95 square kilometres. According to the 2010 Population and Housing Census, the Municipality has a population of 68,597 [21]. The Municipality is generally low lying with granite rocks and isolated hills around Winneba. Ayensu and Gyahadze are the two main rivers that drain the Municipality and enter the sea at Warabeba and Opram respectively [21]. These rivers offer the potential for agricultural development. The Municipality lies within the dry-equatorial climatic zone characterized by low rainfall and long dry season of five-month [21]. The annual rainfall ranges from 400 millimetres to 500 millimetres. Mean temperatures range from 22 degrees Celsius to 28 degrees Celsius [21]. The vegetation is that of the coastal savannah grassland which is suitable for vegetable cultivation or dry season irrigation farming. Major crops cultivated in the area include tomatoes, green pepper, groundnut, okra rice, and maize. The soils in the Municipality are largely clayey [21]. Figure 1 shows the map of the study area.




Source: GSS, 2010

**Figure 1.** Map of Effutu Municipality

### 2.2 *Data collection and analysis*

Although several climatic elements affect agriculture, the researchers used only rainfall, which is attributed as the major factor. The researchers analysed rainfall data obtainedfrom the Ghana Meteorological Agency (GMet) across a twenty-four-year period from 1995 to 2018. Analysis of climate variability often requires at least a thirty-year period, however, there was a data gap which compelled the researchers to use the said time series. Due to the gap in climatic data obtained from GMet, the twenty-four-year data on rainfall over the study area was sliced to twenty years. Thus, the twenty-year rainfall data used for the purpose of this analysis spanned from 1999 to 2018. The main reason for slicing the rainfall data into a 20-year period was to aid in grouping the data into a decadal form (10 years in a group) for easy comparative analysis. In view of this, there were two Decades of Rainfall (DoR) distribution. The first DoR spanned from 1999 to 2008 whiles the second DoR spanned from 2009 to 2018. Since there are two main rainy seasons in the Effutu Municipality which lies in the Dry Equatorial climate, each DoR was further grouped into two: major rainy season (April to July) and minor rainy season (September to November).

Furthermore, time-series data over an eight-year period from 2010 to 2018 on rice, green pepper and maize production and yield was obtained from Ministry of Food and Agriculture (MoFA) and utilised. MoFA unit at the Effutu Municipality had limited data on crop yield. Due to this, only the output of rice for the eight years was used. This data was used to ascertain trends and patterns ininterannual rainfall distribution and interseasonal one (that is, the major and minor seasons) for the twenty years period. In addition, the researchers also assessed the relationship in the pattern of annual rainfall distribution and crop yield over the eight-year period. To be able to answer the research of what adaptive practices are used, the researchers organised a focus-group discussion involving 7 farmers. The responses from the focus-group discussion were analysed thematically.

PCI values for determining rainfall concentration are calculated as $PCI = 100 \times \{\sum PI^2/(\sum PI)^2\}$ where PI is the rainfall amount of the $X^{th}$ (for each decade of both seasons) and $\sum$ is the summation of the two decades (20 years). PCI lower than 10 suggests a uniform concentration; values between11 and 20 indicate high concentration, while those above 21 are considered very high rainfall amounts [20].

The researchers sought to establish the correlation between the patterns of rainfall distribution and the output of major crops grown in the Effutu Municipality. There appeared to be traces of inaccuracies in the data obtained from MoFA unit at the district especially on green pepper and maize production. However, due to the presence of the Okyereko Water Users Association which is responsible for monitoring and purchasing rice output within its environs, an eight-year period somewhat reliable data was obtained on rice.

# 3. Results and discussions

## 3.1 *Seasonal variation in rainfall*

The data showed a significant disparity in the amount and distribution of rainfall between the major and minor seasons. For example, the major season (April to July) for the first decade (1999-2008) recorded an average rainfall of 142 mm whereas the major season (April to July) for the second decade (2009-2018) recorded an average rainfall of 90.1 mm. This shows a significant decrease in rainfall within the major seasons for the past twenty years. With the minor season (September and October), the first decade recorded an average rainfall of 88.5 mm whereas the minor season for the second decade recorded a significantly low rainfall average of 48 mm. Although both seasons showed a decreasing pattern in rainfall, the major season showed higher variability in rainfall patterns.

The coefficient of variation was computed for the two seasons over the two decades. The results showed a higher variability in the major season (CV, 6.5%) than the minor season (CV, 5.1%), though both showed variability. The total average rainfall of the major season decreased by 51.9 mm, whereas the minor season decreased by 40.8 mm over the two decades. The variations in the average rainfall for the major and minor seasons for the two decades are shown in Figure 2 and Figure 3 respectively.

From the results above, it is clear that there is high seasonal variation in rainfall within the Effutu Municipality for the past twenty years. Both rainy seasons have experienced variation, with the major season having higher variability in rainfall. The PCI value calculated for both seasons was 19 which is an indication of a relatively high concentration of rainfall for crop production within the two decades (1999-2018). However, examining the trend in the rainfall distribution for the past twenty years shows a general decline in rainfall for the area. This has serious implication for arable farming. This finding gives credence to Kyei-Mensah, Kyerematen, and Adu-Acheampong's [20] observation that there is a general reduction in the distribution of rainfall for the past 30 years (3 decades). This requires more adaptive activities for the farmers in the Dry Equatorial climate, particularly for the Effutu Municipality. This reduction in rainfall distribution exacerbates the already persistent problems including pest and diseases and post-harvest loses posed to farmers identified by Yengoh et al. [21]. Yengoh et al. [21] posit that the amount and distribution of rainfall affect many other aspects of agricultural production including farm sizes, crop enterprises, cropping calendars, incidence and growth of weeds, crop pests and diseases.

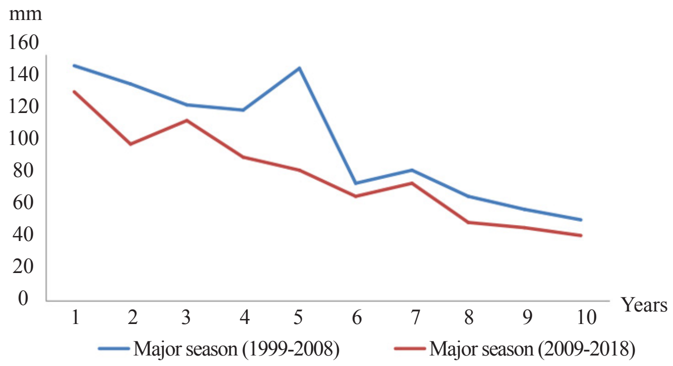



**Figure 2.** Average rainfall variations in the major seasons for the two decades

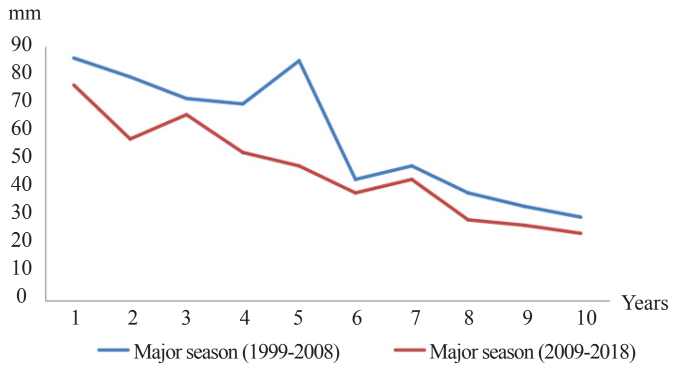



**Figure 3.** Average rainfall variations in the minor seasons for the two decades

## 3.2 *Correlation of rainfall patterns with major crop output in Effutu Municipality*

The output levels of rice were estimated in the number of mini (25 kg) or big sacks (50 kg) per hectare of land. In view of this, the values for output used in this analysis were measured in the unit mentioned earlier. A necessary assumption that the farm sizes on which such data was collected remained the same throughout the study period was made. The output of rice for an eight-year (2011-2018) period was correlated with an eight-year (2011-2018) interannual rainfall distribution to determine trends and patterns. Figure 4 below shows the output levels of rice and the interannual rainfall distribution for the period of 2011 to 2018.

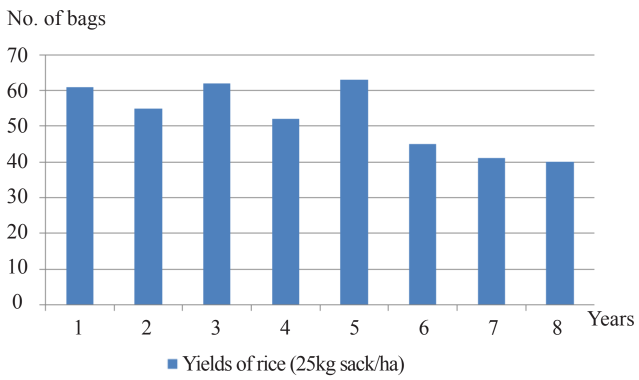



**Figure 4.** Yields of rice from 2011 to 2018

Figure 4 above shows a general decline in the output of rice production, especially for the past three years. The average output per year has decreased from 60 units of the 25 kg sack to 40 units, and even less in some few cases. This trend in rice production perhaps corroborates the reduction in rainfall patterns for the same period under study. From the focus group discussions, some of the farmers indicated the following.

'For the past few years, the rains have reduced drastically. It does not rain as it used to be. This has reduced crop output in general although we try to carry out some form of irrigation. The irrigation method is expensive and hence, most farmers find it an uncommon adaptive activity.' (Field interview, 2019)

The researchers used the Pearson product-moment correlation coefficient to ascertain the correlation between rainfall pattern and yield. This helps to better establish the pattern and strength of the relationship between crop output and patterns of rainfall distribution for the period of 2011 to 2018. The summary of the statistical test performed using Statistical Package for the Social Sciences (SPSS) version 20 is shown in Table 1 below.

**Table 1.** Pearson moment correlation coefficient between rainfall and crop yield

| | | Rainfall pattern | Crop yield |
|---|---|---|---|
| Rainfall pattern | Pearson Correlation | 1 | 0.460 |
| | Sig. (2-tailed) | | 0.252 |
| | N | 8 | 8 |
| Crop yield | Pearson Correlation | 0.460 | 1 |
| | Sig. (2-tailed) | 0.252 | |
| | N | 8 | 8 |

*Significance level at 0.05
Source: Field data (2019)

From Table 1 above, the Pearson moment correlation coefficient, r, between rainfall and crop yield (rice) is 0.460. The 'r' value obtained portrays a moderate positive relationship between rainfall and rice production. By implication, the more the rainfall amount recorded within the period of study, the higher the output of rice in the Effutu Municipality. However, given a P-value of 0.252, the relationship is not enough to conclude that higher rainfall amount would always yield higher output. This may be attributed to other factors that equally affect crop production including pest and diseases, farm size and pre-cultivation planning among others. For instance, Yengol et al. [22] stressed that rainfall has the potency to affect the incidence and growth of weeds and crop pests and diseases.

This relationship between rainfall distribution and crop yield was agreed to by both the farmers and other stakeholders. The farmers, especially those farming away from the Ayensu, indicated that their family activity is purely rain-fed, and that, the current decline in rainfall amounts is adversely affecting crop production. For instance, one of the farmers indicated that,

'Over the past few years, the rainfall pattern has not been favourable at all. The situation has been critically worst for the past three years. Last year, during this period in June, there were no rains and so most of the crops we cultivated died out. This adversely affected crop yield.' (Field interview, 2019)

This was confirmed by the office of MoFA.

'Yields for most crops including rice, maize, and some vegetables have gone down for the past few years. There is sometimes an intermittent increase in the output due to rainfall variability. However, the general trend is a typical indication of a decline.' (Field interview, 2019)

The interview responses above corroborate the statistical index induced by the Pearson moment correlation coefficient as it showed a positive relationship between rainfall distribution and crop yield, especially for the case of rice production within the Effutu Municipality.

## 3.3 *Adaptation strategies used by farmers within the Effutu Municipality*

Adaptation options point to a set of actions, strategies, processes, and policies that farmers are using to respond to actual or expected seasonal rainfall variation so that the consequences for individual farmers, communities, and economy as a whole are minimized [5]. Within the Effutu Municipality, most farmers are vulnerable to the dictates of the seasonal variations in rainfall as they totally depend on rainfall for their farming activities. These rural farmers do not access to credit to finance their agricultural activities. This in no small way adversely affects their scale of production.

Only a few farmers whose farmlands were located along the Ayensu River carry out some form of irrigation. Irrigation farming was considered very expensive adaptive activity. In view of this, most of the farmers do not carry out off-season farming activities including irrigation. For instance, a farmer indicated that,

> 'Farming in recent years has been very hectic due to the decline in rainfall distribution. Most farms far away from the Ayensu River are often left with no option but to suffer production losses as a result of acute rainfall decline. However, few large scale farms found along the Ayensu River in Atenkyedo, for instance, carry out irrigation farming for crops including rice, maize, okra, and green pepper.' (Field interview, 2019)

Figure 5 shows evidence of irrigation farming practised on farmlands along the Ayensu River.

Source: Field work, 2019

**Figure 5.** Irrigation pipe laid across farmlands

## 4. Conclusions and recommendations

The study sought to assess the impact of seasonal rainfall variation on arable farming within the dry Equatorial climate, particularly in the Effutu Municipality of the Central Region, Ghana. Local rainfall data spanning over twenty years was analysed for trends of variability and correlated with crop output, particularly rice in this case. It further examined the adaptive practices used by farmers in the face of climatic variability.

The study showed that, although there was relatively enough rainfall for crop production for the past two decades, rainfall patterns were variable especially for the major seasons. The rainfall data showed a general decline in rainfall distribution in both seasons, very severe in the past three years.

Correlation between rainfall distribution and the output of rice for the period under study showed a positive relationship although such a relationship was found to be statistically insignificant. High rainfall patterns corresponded to high outputs of rice in Effutu. However, such a relationship was not enough for output monitoring in the face of high variability coupled with other factors such as farm sizes and pest and diseases. The aforementioned factors affect farming practices in the area.

The findings showed that only a few farmers are able to carry out irrigation farming due to the cost involved. In view of this, the study recommends timely intervention by government in financing irrigation farming within the area. This is because there is great potential for agricultural development within the municipality. On-farm adaptation strategies such as the delay of panting date, changing the cropping system, using mulch and the drought resistance variety of crops can be tried.

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## Conflict of interest

It must be indicated that the authors have no such issue of conflict of interest in undertaking and reporting on the research problem.

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