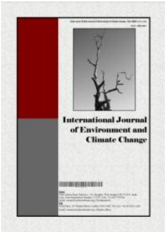

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Climatic Conditions and Agricultural Production in Lower Zio Valley (Southern Togo)

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

This study was carried out in the lower Zio valley, an area located between a latitude of 6.13° and 6.20°N and a longitude of 1.04° and 1.32°E. This zone has increasingly undergone significant climate change in recent decades. The main consequence of this climatic phenomenon is the decline in the standard of living of rural communities whose main economic activity is agriculture. This research aims not only at investigating the variations that characterize the climate but also at analyzing the impact on agricultural production at the scale of the research site. The data of certain climatic parameters such as Rainfall, temperature and evapotranspiration from the period 1981-2020 were used in order to achieve the objective of the study. The Standardized Precipitation Indices (SPI), the Martonne aridity indices, the Lamb index and the Pettit test are the statistical treatments used to describe the hydro-climatic manifestations of the research area. The results from the various statistical processing of climate data show that the lower Zio valley is undergoing more or less significant climate changes with an upward trend in cumulative rainfall. The standardized index made it possible to highlight the rainfall variations characterized by the alternation of surplus and deficit years. Indeed, the years of increased rainfall are for example: 1999 with 30.27% water surplus; 2010 with 27.2% and 2017 with 22.99%. On the other hand, some of the deficit years are 1983 with 34.70% of deficits; 1992 with -36.98% and 2000 with -34.70%. In addition, the low temperature differences are 1.05°C in Lomé and 0.59°C in Tabligbo. In the end, all these climatic phenomena disrupt the normal course of crop development cycles and provoke lower agricultural yields.

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1. INTRODUCTION

In many regions of the world, the quality of life is based on the primary sector economy which is linked to climate conditions over years or periods. These conditions were consistent in many cases with traditional agricultural calendars in the past. However, they have been subject in recent years to modifications that affect the agricultural systems of regions with limited adaptive capacities [1] Consequently, if populations from irrigated agriculture continents can more or less escape these climatic upheavals, this is not the case in the West African region where the majority of workers are employed in the agricultural sector. The factors explaining the climatic conditions of this region have already been reported by several authors [2-9].

In Togo, for example, several researches including those of [10-13] have indicated the dependence of the agricultural sector on the climate and especially on the evolution of the growing seasons. One of the objectives of the FAO (the Food and Agriculture Organization of the United Nations) is to encourage the increase of agricultural production by means of modern techniques [14]. Similarly, to other areas in Togo, the Zio basin is currently undergoing an increasingly sensitive climate change. This disruption is manifested by uncertainties for the beginning and end of agricultural seasons, an increase in dry spells at the center of the farming season, false starts and a concentration of rainfall over relatively short periods [15]. Agricultural productivity and the living conditions of the populations in the research area are thus put on strain. Consequently, rural communities of the lower Zio valley, whose main activity is agriculture, see their standard of living drop considerably. The lower Zio valley, which is the study environment, is located in the southern part of Togo and straddles the crystalline basement and the coastal sedimentary basin [16]. It is dominated by detrital formations of a clayey-sandy nature called barre land suitable for growing corn and cassava. The aim of this study is to analyze the climatic variations on the scale of the lower Zio valley in order to access its impact on agricultural production. The study area is presented in Fig. 1.

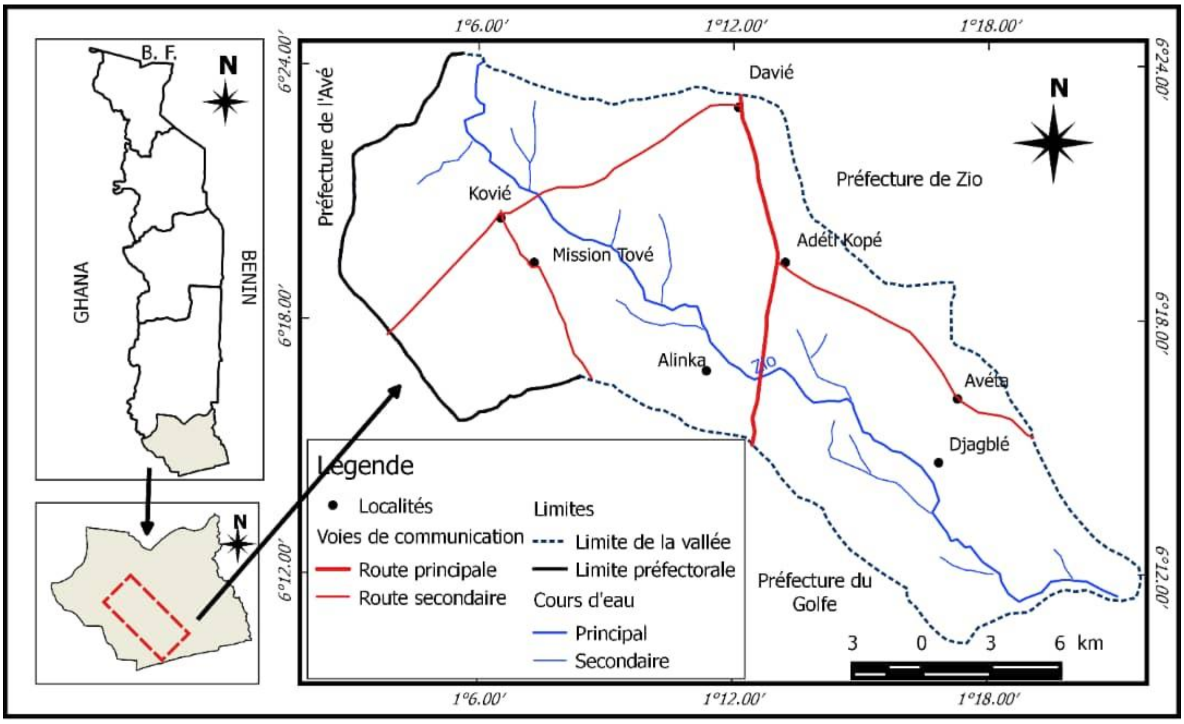

Fig. 1. Map of the study area
Source: IGN topographic map, Lomé sheet NB-31-XIV-XIII (1980) and field work, 2022.

2. METHODOLOGY

The data used in this study were obtained from meteorology and fieldwork. The analysis was carried out after processing the collected data.

2.1 Data Used

For the purpose of this study, the climatic data on rainfall amounts, daily temperature and Evapotranspiration (ETP) from the Tabligbo synoptic stations (06°35' north latitude, 01°30' east longitude) and Lomé (06°10' north latitude and 01°15' east longitude) were collected from the Togolese Meteorological Agency (DGMN). These climatic data ranged from 1981 to 2020, i.e. 40 years. The two stations were selected because they are synoptic stations and, consequently, the meteorological parameters are valid over a radius of 25 km. The choice of the 40-year period for the study is explained by the fact that the changes in the rainfall pattern of the Zio valley have been really felt from the 1980s until today. The agricultural statistics data collected relate mainly to maize and cassava production. Agricultural data ranged from 1990 to 2020 because of their unavailability for much more remote periods. The two agricultural speculations (maize and cassava) were selected because of their importance in the farming and food habits of the populations in the study area. In addition, field surveys of communities and participants (agents working in the field of rural development, etc.), observation of the landscape have made it possible to better understand the effects of climatic upheavals on agricultural activities in the study area.

2.2 Data analysis

The methods used for the analysis in this research allowed the characterization of climate change and the correlation between rainfall and agricultural production.

2.2.1 Characterization method of climate variability

Descriptive statistics were used to a characterization of climate variability. The mathematical formula used is as follows:

$$\overline{X} = \frac{1}{N}\sum_{i=1}^{n} xi \qquad (1)$$

where $\overline{X}$ = mean, xi = rainfall value for a year; ∑ = sum; N = number of years.

For the analysis of the interannual evolution of rainfall, the Lamb index (1982) is used. This index is calculated according to the equation:

$$ISP = \frac{pi - \bar{P}}{S} \qquad (2)$$

where SPI is the standardized precipitation index; pi is the annual precipitation depth (mm); $\bar{P}$ is the mean (mm) of the reference period considered (1981 to 2020); S is the standard deviation of the reference period (mm). For each threshold, the percentage of the number of times that SPI is above or below the values is calculated over several years. Thus, on the basis of precipitation thresholds [17] the thresholds recorded in Table 1 is used for the purpose of this study.

Table 1. Standardized Precipitation Index thresholds

Value	Interpretation
SPI > 2	Extremely wet
1< SPI < 2	Severely wet
0< SPI < 1	Moderately wet
-1< SPI < 0	Moderately drought
-2 < SPI < -1	Severely drought
SPI < -2	Extremely drought

Source : [17]

The SPI threshold values are used to determine severely wet and severely dry years, wet and dry years; then moderately wet or moderately dry years shown in Table 1. The [18] made it possible to detect the years of break and to compare the means in the studied rainfall series. The absolute value ***t*** that is the difference between the mean before break and the mean after break is compared with the value on the Student-Fisher table (1973) whose degree of freedom is:

$$v = n_1 + n_{2-2} \qquad (3)$$

The difference between the means of the two sub-periods is significant if the t value is greater than that the Student-Fisher table at the threshold of 0.05. It is very significant if the ***t*** value is greater than the threshold of 0.1.

2.2.2 Result analysis from climate and agriculture production correlation

The graphic correlation between climate and agricultural production facilitates the analysis of the influence of rainfall variations on crops in the period 1990 to 2020. The approach consists in representing the values of agricultural production and the interannual rainfall heights. As a result, it is possible to detect good or bad years depending on whether the maize and cassava production curves are higher or lower than that of cumulative rainfall.

3. RESULTS

The results listed in the following tables relate mainly to the analysis of rainfall and temperature data and their influence on agricultural productivity.

3.1 Analysis of Rainfall Conditions

This section studies the inter-annual variations in cumulative rainfall and their trend evolution.

3.1.1 Evolution of the interannual means of cumulative rainfall

The interannual evolution of precipitation listed in Fig. 2 below facilitates the analysis of the variations in the heights of rain and the assessment of the trend of the investigated time series.

The evolution of the SPI curve (Fig. 2) shows two phases in the interannual variations of precipitation both at the Lomé station and at Tabligbo. At the Lomé station, the first phase which runs from 1981 to 2003 is marked by rainfall deficits. For example, during the 1990s; 1992; 1998 and 2000 respectively recorded negative SPIs of -0.91; -1.62; -1.81 and -1.91. The deficit period observed in Tabligbo covers approximately the same decades (1981-2003) as that of Lomé. In Tabligbo, for example, we remember the years 1983; 1986; 2000 and 2005 with SPIs of -1.61 respectively; -1.26; -1.82 and -1.21. These years of rainfall deficits have probably influenced crops, which can suffer from water stress to varying degrees leading to the increases in the risk of reduction of agricultural yields. On the other hand, the positive anomalies which mark the abundance of the rains are observed after 2005 until 2020 with values ranging from 1.21 to 2.83 both at the Lomé station and at the Tabligbo station.

3.1.2 Trend and break in stationarity of rainfall series

The detection of breaks in stationarity using the Pettit test enabled not only the assessment of the variations observed in the series but also the comparison of the means of the two identified sub-periods (Fig. 3).

Fig. 3 shows that there is no break in stationarity in the series of data from the Lomé station. On the other hand, there was a break in 2012 at the Tabligbo station. Thus, the climatic situation is characterized by deterioration in rainfall before the year of break at the Tabligbo station. Indeed, the mean X1 (1022.37 mm) before the year 2012 is lower than the mean X2 (1037.66 mm) afterwards, i.e. an increase of 1.49%. The break in stationarity has significantly impacted agricultural activities, particularly in the choice of varieties of agricultural seeds. This sudden break provokes a difficulty for the different cultivated crops until then to adapt to the new climatic conditions. The rainfall and thermal referendums are disturbed and they provoke therefore a decline in agricultural productivity.

3.2 Analysis of Thermal Conditions

The analysis of the thermal conditions of the reference period (1981-2020) focuses mainly on the high and low temperatures.

3.2.1 Evolution of the interannual average high temperatures

The interannual evolution of average high temperatures is analyzed from Fig. 4 below. It allows the identification of the high thermal conditions under which crops grow in the research area.

The evolution of the interannual average high temperatures in Fig. 4 highlights two main phases. Indeed, the high temperatures are much lower in the period between 1981 and 1996 in Lomé. It was after 1966, the year of the break, that they experienced a slight increase until 2020. At the Tablibgo station, the increase is observed from 1997, the year of the break. The increase in temperatures is valued +0.88°C in Lomé and +1.89°C in Tabligbo. This situation marked by an increase of the temperatures is not likely to promote good agricultural productivity.

3.2.2 Evolution of interannual average low temperatures

The interannual evolution of low temperatures is illustrated in Fig. 5.

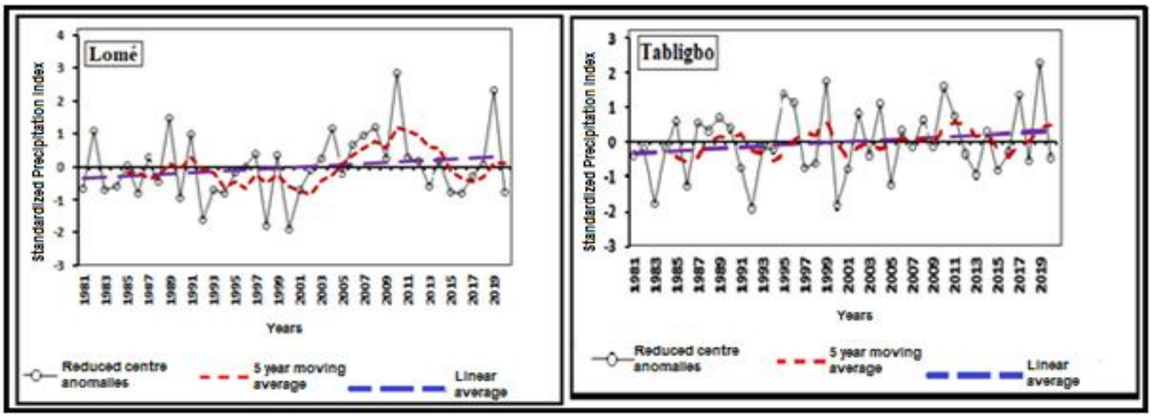

Fig. 2. Interannual evolution of precipitation from 1981 to 2020
Source: F. Lemou (2022), data from Togolese Meteorological Agency

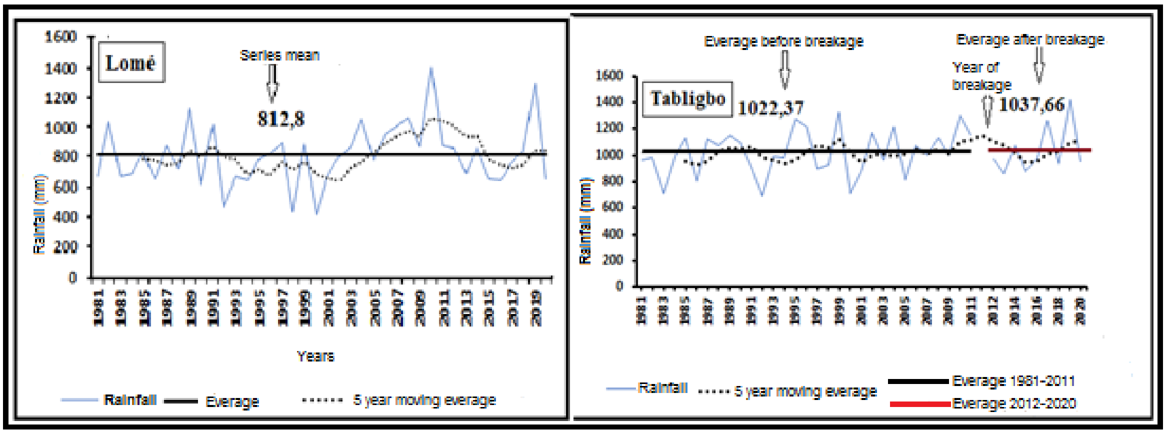

Fig. 3. Trend of stationarity according to the Pettit test in the period (1981 to 2020)
Source: F. Lemou (2022), data from Togolese Meteorological Agency

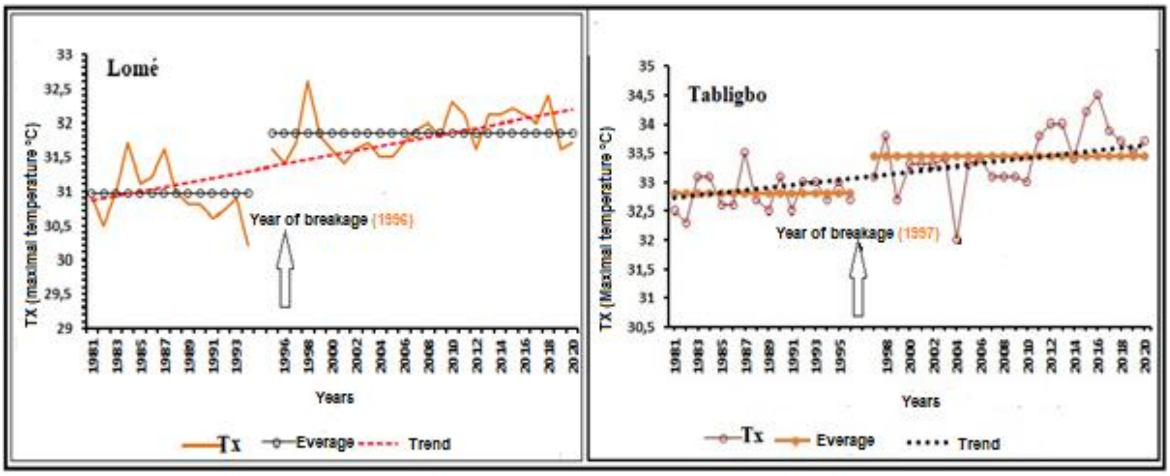

Fig. 4. Trend evolution of the highest temperatures from 1981 to 2020
Source: F. Lemou (2022), data from Togolese Meteorological Agency

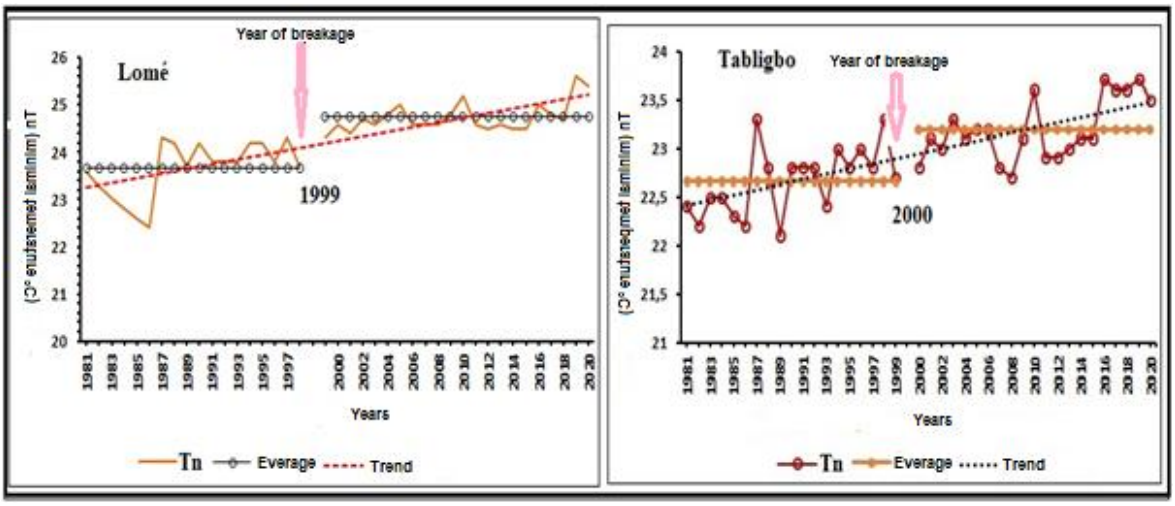

Fig. 5. Trend evolution of the low temperatures from 1981 to 2020
Source: F. Lemou (2022), data from Togolese Meteorological Agency

Table 2. Comparative averages of temperatures before and after break

Stations	Parameters	Years of break	Average before break °C	Average after break °C	Difference °C
Lomé	Tn	1999	23.65	23.74	1.05
	Tx	1996	30.97	31.85	0.88
Tabligbo	Tn	2000	22.66	23.19	0.59
	Tx	1997	32.80	33.44	1.89

Source: F. Lemou (2022), data from Togolese Meteorological Agency

The results in Fig. 5 above show an upward trend in low temperatures both at Lomé station and at Tabligbo station. This increase is evaluated, after the years of break in the series, at +1.05°C in Lomé and at +0.59°C in Tabligbo; this is an indicator of global warming that is increasingly affecting the study area. Table 2 below shows the average temperatures compared before and after break.

The results in Table 2 show a more significant low temperature difference in Lomé. Indeed, there is a difference of 1.05°C while it is only 0.59°C in Tabligbo. On the other hand, the high temperatures indicate greater differences at the Tabligbo station (1.89°C) than at Lomé (0.88°C). The higher difference in low temperatures observed in Lomé creates a thermal environment that influences the normal growth of crops. It can negatively impact agricultural yields. According to [19] the thermal requirement of cassava is between 23-24°C while maize has a thermal preference of between 18-20°C. But the low temperatures recorded in the two stations are between 22 and 24°C. On the basis of these thermal preferences and the low values observed in the study area, it can clearly be seen that the maize crop will have to suffer the most from climatic discomfort.

3.3 Impact of Rainfall Variations on Agricultural Production

Agricultural yields are influenced by rainfall conditions in the study area. This influence is highlighted by the correlations in Fig. 6 below in the period between 1990 and 2020.

The indices from the rainfall-production correlation are not perfect (Fig. 6). In Lomé, the maize indices describe an insignificant intensity relationship (R = 0.45); which explains a less significant line of progression. For cassava, on the other hand, a correlation of medium intensity is established with R = 0.53. In Tabligbo, these indices describe a relationship of low intensity for maize (R = 0.24) and medium intensity for cassava (R = 0.53). Although the variation in these indices, they show a positive relationship everywhere and implies that rainfall variations really influence maize and cassava production to various degrees. For certain years, we also

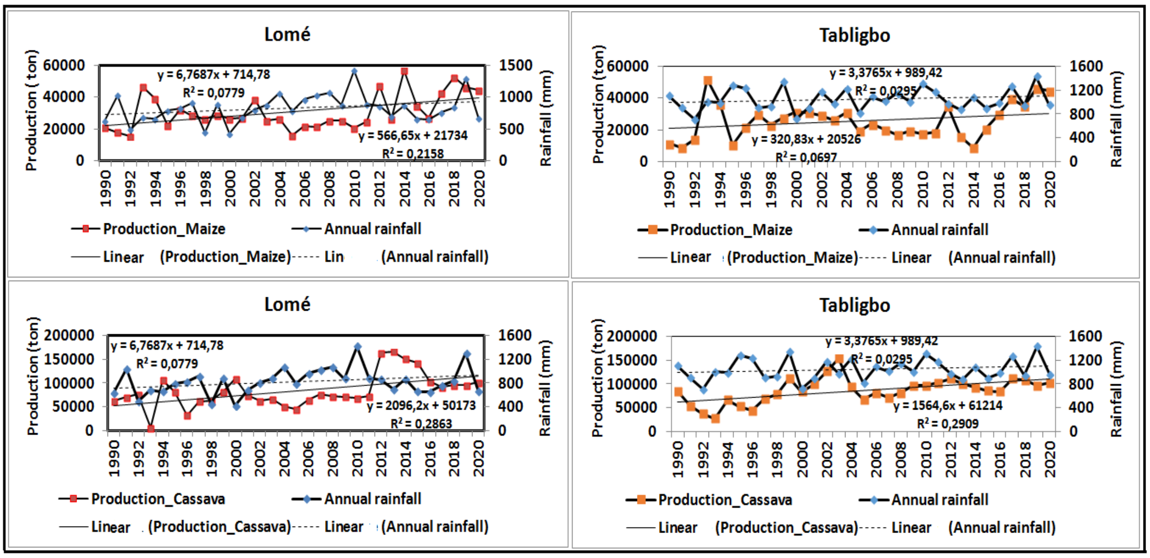

Fig. 6. Graphical correlations of rainfall - agricultural production

Source: F. Lemou (2022), data from Togolese Meteorological Agency and the Department of Agricultural Statistics, Informatics and Documentation

observe good rainfalls which correspond to those of good agricultural production. In the case of maize, it is the years 1996; 2012; 2014; 2018 and 2019 while for cassava it is the years 1999; 2012; 2014; 2018 and 2019. The years when low maize production is observed are 1990 and 1992 with deficits of -31.9% and -49.4% respectively. For cassava, major deficits were recorded in 1993 with a value of -92% though this year did not correspond to the driest year in the series. As a result, the years of good agricultural production do not necessarily correspond to the years of significant accumulations of rainfall and vice versa. After all, rainfall extremes compromise agricultural productivity in the study area. For example, rainfall deficits or excesses can lead to lower crop yields, especially when these extremes occur during critical crop growth phases. However, it should be noted that rainfall conditions alone do not explain the fluctuations in agricultural yields. Soil, human and technical factors can still contribute to good or bad agricultural production.

4. DISCUSSION

The study was based on reduced centered indices to explain the rainfall and thermal conditions in which agricultural activities develop in the lower Zio valley. Without questioning the results, it important to remind that these indices include the average, a central trend that hides certain disparities. The analysis of the two main climatic parameters mentioned above permitted to describe the interannual variations in precipitation and the trend increase in temperatures. Dry and wet episodes occurring along the series were also detected. This climatic reality has also been found by J. Poitout et al. [20] who confirm that recent decades have been increasingly marked by an increase in the frequency, intensity and extent of exceptional climatic disturbances. Moreover, this study shows that the period from 1983 to 2003 was particularly marked by a significant drop in rainfall. In Senegal, a methodological approach similar to ours enabled [21] to detect the decades from 1983 to 2003 as those characterized by a notorious scarcity of rainfall in the Haute-Casamance sector. The spatio-temporal variability of precipitation has been studied by K. M. Badameli [10] in his work on the same climatic zone as the present study. He has come to the conclusion that a year or a series of years with a positive anomaly for a given station can turn out to be negative for another neighboring station. A break in average rainfall with an increase of 1.49% was observed in the series of the Tabligbo station in 2012, while no break was indicated in Lomé. This result corroborates the study of A. Afo-Dogo [22] who identified significant breaks in the average rainfall series at the Lomé station in 1976 and at the Tabligbo station in 1968. These differences in the years of break testify precisely the spatio-temporal variability of rainfall also described by K. S.M. Badameli [23]. The analysis of the series of thermal data from the two stations also shows a trend increase in the maxima and minima. Indeed, the difference between the averages before and after break shows an increase of 0.88°C in Lomé and 1.89°C in Tabligbo for high temperatures. On the other hand, for the minima, this increase is 1.05°C at the Lomé station and 0.59°C at the Tabligbo station. These results are very similar to those of A. Afo-Dogo [22] who believe that the breaks observed in the averages of the series describe perfectly the climatic instability that began in the 1970s in the West African sub-region. It is therefore in this climatic atmosphere that many farmers in the study area often start the growing season in a spirit of uncertainty because they are aware of the risk of rainfall discomfort which can considerably compromise the level of agricultural yield.

5. CONCLUSION

Statistical analysis of the rainfall series in the period between 1981 and 2020 collected from the Lomé and Tabligbo stations permitted to detect strongly negative ISPs which characterize the years of deficit observed in both Lomé and Tabligbo. Among the Lomé series, the years 1992, 1998, 2000 are theoretically described as dry years with respective reduced centered index values of -0.91; -1.81; and -1.91. In Tabligbo, it was rather the years 1986 and 2000 which were much drier with respective SPI values of -1.26; -1.82. Similarly, extremely wet years with excess rainfall of more than 1.40% compared to the average were observed in the series under study. With regard to thermal conditions, the research has shown a trend increase in high and low temperatures at the two stations (Lomé and Tabligbo). Thus, the climatic discomfort due to the instability of the two main parameters (rain and temperature) disturbs the normal process of crop growth. Indeed, the results of graphical correlation rainfall-production of maize and cassava crops have clearly shown a certain influence of rainfall variations on agricultural productivity though the lack of seasonal rains does not necessarily imply poor agricultural yields. Similarly, good seasonal rainfall does not guarantee good agricultural production. There are therefore other factors such as soil, technical and human conditions that can also compromise agricultural productivity. But this climatic situation still intensifies the uncertainty of agricultural production forecasts in the study area and makes peasant populations much more vulnerable because their socio-economic living conditions are increasingly deteriorating.

It is therefore necessary to continue the work in order to identify the options for sustainable agricultural production that is less dependent on the climate in this lower Zio valley.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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