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Climate variability and incidences on agricultural production in the municipalities of Dassa-Zoume and Glazoue in the center of Benin

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Abstract

The present work studies climate variabilities and theirs incidences on the agricultural production in Municipalities of Dassa-Zoumé and Glazoué. It is based on the analysis of thermal pluviometric data of the insolation, and the climate balance assessment, in order to estimate the climate characteristics on the agricultural production in Municipalities of Dassa-Zoumé and Glazoué. The methodological approach consisted in the calculation of climate parameters. The results revealed a very large variability of the rainfall from one station to another and that this significant variation of the precipitation represented a disruptive factor for the agricultural activities. The monthly average values of the calculated temperatures showed a variation between 25 and 30.5°C with effects on respiration and photosynthesis of plants therefore triggering a regression of the activities of agricultural production.

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Introduction

Agriculture represents the basis of the economy in Benin (Puttevils, 1999). Therefore, it plays an essential role in the process of economic and social development (FAO, 2005). Still, with the climate hazards which have been impacting the farming sector since the 1970s (Vignigbé, 1992), there is a good reason to be interested in their consequences on Beninese economy and mainly on food supply for the rural populations.

In Benin, the reduction in rainfalls coupled with the thermal reheating, lead to a degradation of the ecological environment and result in negative impacts on agricultural production (Boko, 1988; Afouda, 1990; Houndénou, 1999).

Agbossou and Akponikpe (1999) join in this context and assert that from 1960 till 1992, serious pluviometric shortages were recorded and resulting in harmful incidences on the agricultural yield of the main crops. Thus, the access to food supplies becomes one of the major concerns highlighted in the new orientations of Beninese agriculture.

Municipalities of Dassa-Zoumé and Glazoué, although being part of Collines Department considered to be an agricultural center - because of its available lands favourable to the culture of foodstuffs and although it welcomes the largest number of agricultural populations coming from overpopulated regions or those from less fertile soils – is confronted with problems of climate hazards which have certainly impacts on agricultural production. The aim of this research is to analyze the climate parameters and to assess their incidences on the agricultural production.

Materials and methods

Data collected

The data collected within the framework of the present investigation are pluviometric data from Dassa-Zoumé and Glazoué between 1950 and 2010 as well as the thermal data (minimal, maximal and average temperatures), of insolation and winds of Savè between 1965 and 2010 in order to estimate the climate characteristics on agricultural production in the Municipalities of Dassa-Zoumé and Glazoué.

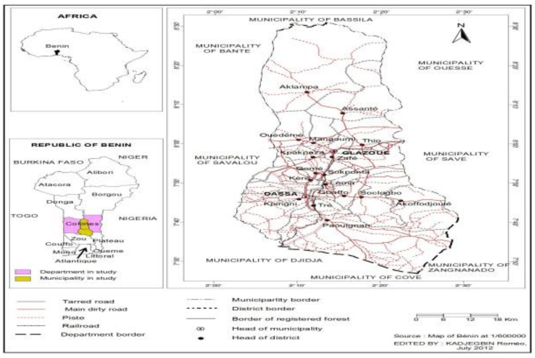

Fig. 1. Geographical location of the Municipalities of Dassa-Zoumé and Glazoué.

Data processing methods

Soil Water balance

In a given region, a good knowledge of the climate, soils and water required for crops allows us to estimate the food supply issues which can arise in certain periods. Assessing the water content balance means comparing the quantity of water necessary for the crops with the one that is available in the soil. These two values vary constantly over time according to the stage of the crop and the climate conditions (rainfall and potential evapotranspiration) that allow to figure out the inputs and outputs of the water balance. There are two types of balance: the real balance and the potential balance. Actually, thanks to its root system, the plant can prospect the soil and draw from the useful water reserve of the soil. The water balance thus consists in estimating the store of water in the soil and its changes during the cycle of the crop. It is useful to better know the environment and the relations climate-soil-plant which take place during the cycle of the crop. They allow us to better know the amount of water to be used, the right time of the supply and thus to make the diagnosis of the functioning of an irrigation system. During the vegetative cycle of a plant, when the pluviometry is lower than the maximal evapotranspiration, the plant appeals for water contained in the useful store of the soil to survive. If this period goes on, there is a moment when the useful store is exhausted. This results in reduction of its photosynthesis as soon as the UBR (Useful Basic Reserve) is exhausted. The formula is the following one:

P-D-R = RET + (final H - Initial H) of the soil
P = rainfall or irrigation;
D = drainage;
R = water runoff in mm over the considered period;
RET = real evapotranspiration of the crop;
(Final humidity - Initial humidity) = A RU and difference between the quantity of water in the horizons of the soil (profile) exploited by roots between the end and the beginning of the considered period (mm). The principle of water balance attempts to consider the soil as a water tank and assess through calculation the state of this reserve by taking into account the quantity of water consumed by the crop and the supply by precipitation or irrigations.

Analysis of precipitations at ten days scale

In order to analyze the precipitation in the study area, the data of both pluviometric stations (Dassa and Glazoué) were used. The average of the pluviometric data is calculated in normal conditions between 1950-2010. The daily rainfall heights were considered on ten days basis. The precipitations are controlled in the study area at the level of two pluviometric stations and one synoptic station (Savè).

Arithmetic mean

It is used in the study of the climate and hydrological regimes over a period of thirty years for the climate and hydrological characterization in the dynamics of the river. Its formula is:

$$\overline{\mathrm{X}} = \frac{1}{n} \sum_{i=1}^{n} xi$$

It allows the calculation of certain dispersal parameters.

Standard deviation

It is the square root of the variance. It allows us to conduct a study on the dispersal of the pluviometric and hydrological annual values obtained over the period of recording at the station considered.

Its formula is the following: $\eth(\mathbf{x}) = \sqrt{\mathbf{V}}$; variance

V is defined as follows:

$$\mathrm{V} = \frac{\mathbf{1}}{\boldsymbol{n}} \sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{n}} (\boldsymbol{xi} - \overline{\boldsymbol{X}})^2$$

Method of calculating the reduced centred values

The precipitations vary from one year to another. To determine the rainy and dry years, the reduced centered distances (Z) are calculated.

$$\boldsymbol{Z} = \frac{X - \mu}{\sigma}$$

Z stands for reduced centerd abnormality for year i
X = value of the variable
μ = mean of the series
σ =Standard deviation of the series

Analysis of the evapotranspiration at ten days scale

PET (Potential Evapotranspiration) is the evaporative capacity of the atmosphere on a soil covered with vegetation having water in abundance. It is conducted when on one hand the vegetation is in a state of active life and covers well the soil and when on the other hand the water supply does not represent a limiting factor of its development.

$$\boldsymbol{Z} = \frac{X - \mu}{\sigma}$$

Z stands for reduced centered abnormality for year i
X = value of the variable
μ = mean of the series
σ =Standard deviation of the series

According to Penman, 1954; Thornthwaite *et al.* 1957; Robelin, 1962; the value of PET can be considered as independent of the nature of the setting of plant cover. Therefore it can be estimated at the scale of month or decade, considering the climate data.

From an agronomic point of view, PET corresponds to the water optimal regime of plants; it is thus an important indicator which allows us to characterize the climate and its evaluation integrates several factors such as temperature, insolation, wind, hygrometry.

In Benin, PET is calculated over a period of ten years on six synoptic stations. The values of PET used within the framework were averages calculated between 1950-2010 on four synoptic stations.

Calculation of water balance

The calculated water balance is global; it takes into account only the value of precipitations minus those of PET over a decadal period. At Savè, the water balance is positive starting from the 16th decade till 28th decade, and negative from the 29th decade of year (x) until 11th decade of year (x+1). At Glazoué, the analysis of the results of the calculation of the water balance assessment shows that - contrary to Savè station which is situated upstream, the balance assessment is positive already starting from the 13th decade and remained positie until the 28th decade. From the 29th decade of the year (x) to the 12th decade of the year (x+1), the balance assessment is negative.

Climate balance

It presents the succession of surpluses and water shortages. Thus the climate becomes dry when the precipitations are lower than the potential evapotranspiration, and when there is no reserve of available water (Hufty, 1976, quoted by Vissin, 2007). P*ET al*lows us to express the quantity of maximal water susceptible to be evaporated by a plant cover well spread over the soil, in active phase of growth and watered in an optimal manner (Trochain *et al*., 1980 quoted by Arouna, 2012).

Climate balance assessment represents in particular the rhythm of the surpluses or water shortages. It expresses the difference between the sum of the pluviometry and that of the potential evapotranspiration (PET) and when it is positive it denotes the disposable surplus for the refill in groundwater and for the flow (Sutcliffe and Piper, 1986 quoted by Vissin, 2001, Houndénou, 1999). It also allowed us to highlight the evolution of the climate through the rainy contributions and the losses by evaporation. PET is defined as the climate requirement in steam.

- If P -PET > 0, then the balance assessment is surplus;

- If P – ETP < 0, then the balance assessment has a deficit;

- If P - ETP = 0, then the balance assessment is at fair value.

The climate balance assessment is often used, in particular in a regional study of the hydroelectric resources in West Africa (Thomson, 1985; Olivry, 1993; Le Barbé *et al.* 1993) or still in a study of the hydrological balance assessment in Guinea, in Togo-Benin (Sucliffe and Piper, 1986) and in Benin (Vissin, 2007). It is calculated from the average values of P and PET of the whole dock between 1965 and 2010.

Geographical location of the study area

The study area comprising Municipalities of Dassa-Zoumé and Glazoué (figure 1) is located between 1°41 ' and 2°39 ' 38 " of east longitude and between 7°27 ' and 8°31 ' of north latitude. It is bordered in the North by Municipality of Bassila in department of Donga, in the South by Municipalities of Djidja, Covê and Zagnanado in department of Zou, in the East by Municipalities of Savè and Ouèssè, and in the West by Municipalities of Bantè and Savalou, with a surface area of 3461 km2 and a population of 197817 inhabitants (INSAE, 2002).

Results and discussion

Climate characteristics

Municipalities of Dassa-Zoumé and Glazoué present a climate, transitional between the subequatorial in the South and the Sudanese in the North. In order to assess the evolution of the precipitation, the data of Dassa-Zoumé and Savè stations were used. Besides, in order to estimate better the climate balance, the used data are the ones of the meteorological station of Savè because it is the closest in latitude of Dassa-Zoumé and Glazoué.

Precipitations

Precipitations vary from one year to another. To determine the rainy years and the dry years, the reduced cantered gaps (Z) were calculated. Figures 2 and 3 present the inter-annual variations of precipitations in Dassa-Zoumè and Glazoué between 1950 and 2010.

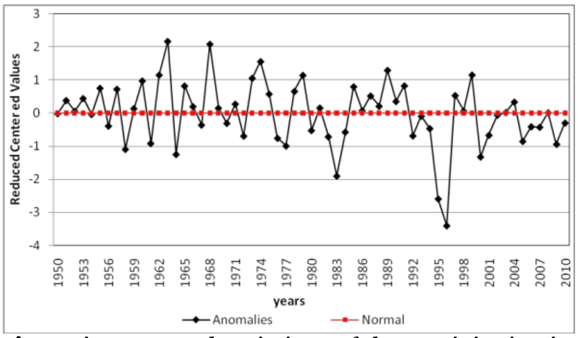

Fig. 2. inter-annual variations of the precipitation in Dassa-Zoumè and Glazoué between 1950 and 2010.
Source: Processing of ASECNA data, 2013.

Over the period of study, the analysis of figures 2 and 3 revealed a very large variability of the rainfall which is represented here. Also, it varies from one station to another. In Dassa-Zoumé, 31 rainy years and 24 dry years compared to respectively 26 and 29 in Savè were recorded. 8 years (1950, 1952, 1954, 1986, 1998, 2002, 2003 and 2008) were merged in the normal axis for Dassa-Zoumé whereas 5 in Savè (1951, 1975, 1978, 1980, 1989 and 2006). At the beginning of decades 70 and 80, the pluviometric recession was very pronounced. But, from the 90s, the increase tended to resume.

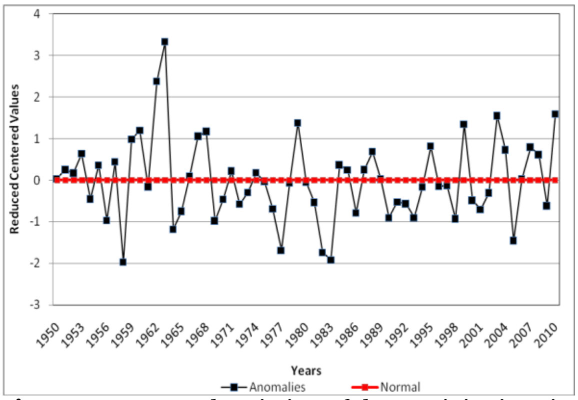

Fig. 3. Inter-annual variation of the precipitations in Savè (1950 to 2010).
Source: Processing of ASECNA data, 2013.

The sensitive variation of the precipitations represents a disruptive factor of the agricultural activities. Therefore the essentially pluvial character of the agricultural production in the Municipalities of Dassa-Zoumé and Glazoué maintains the latter dependent on nature and consequently victim of the climate hazards. Photos (1a and 1b) depict the state of water deficit at the level of corn fields in Dassa Zoumè and Glazoué.

Photos (1a and 1b) above show corn fields in water deficit condition in Kèrè (Dassa-Zoumè) and in Adourékoman 1 (Glazoué). Actually, the hydric deficits prevent the normal growth of the corn in the month (June) normally very rainy in the study area.

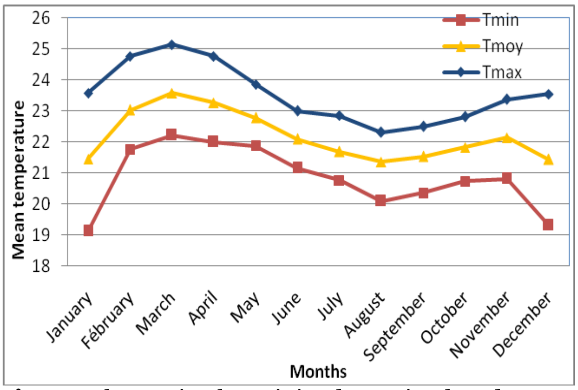

Fig. 4. Change in the minimal, maximal and mean temperatures in Savè between 1965 and 2010.
Source: Processing of ASECNA data, 2013.

Temperatures, insolation and winds

Figure 4 depicts the evolution of the mean temperature in Savè between 1965 and 2010. The analysis of figure 4 revealed that the monthly mean values varied between 25 and 30.5°C. The hottest months were: November, December, January, February and March. It could be explained by the decrease in the precipitation in figure 3.

Actually, the temperature has impact on respiration and photosynthesis of plants. Thus the average values have a lesser impact with regard to the extreme values. This is in accordance with the results of Arouna (2012) and Fangnon (2012). This situation engenders a regression of the activities of agricultural production and triggers rural exodus. Figure 5 presents the evolution of the insolation in Savè between 1965 and 2010.

The analysis of figure 5 revealed that from October to June, the highest values of insolation occurred whereas from July to September the lowest values of insolation were recorded in Savè over the period 1965 to 2010. Indeed, insolation is the essential parameter of the global radiation and plays such an important role at the end the wintering by intensifying the evaporative capacity of air (Sinsin, 1993). Therefore the annual mean duration of the insolation in the study area was of 1740 hours; on the other hand the monthly one was of 289 hours. It reached its maximal value respectively in December and February (205.44 and 209.04 hours) and its minimal value in August (99.36 hours)

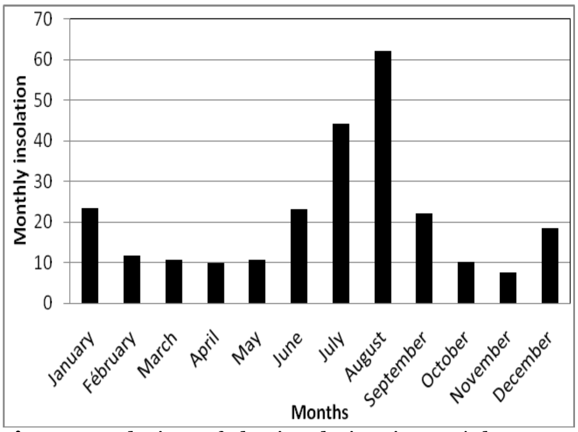

Fig. 5. Evolution of the insolation in Savè between 1965 and 2010.
Source: Processing of ASECNA data, 2013.

In respect of winds, there were two (02) dominant types in Municipalities of Dassa-Zoumé and Glazoué which were the maritime trade wind and the continental trade wind. The maritime trade wind blows from April till November in the southwest direction with an average speed of 3 m/s except in case of thunderstorm where it could reach 9 m/s. During December, January and February, the wind conditions of the sector est or northeast wind determines a particular type of weather, the continental trade wind or harmattan which is a dry wind and which blows between November and March in a northeast direction with an average speed of 2 m/s. These winds which are agents of transport of the masses of wet air, plays a role in the distribution of rains (Boko, 1988).

Climate balance

It presents the succession of surpluses and shortages of water. Thus the climate becomes dry when the precipitations are lower than the potential evapotranspiration, and when there is no reserve of available water (Hufty, 1976, Vissin, 2007). P*ET al*lows to gauge the maximal quantity of water susceptible to be evaporated by a plant cover well spread on the ground, in active phase of growth and watered in an optimal manner (Trochain *et al.* 1980 quoted by Arouna, 2012).

The climate balance assessment thus represents the rhythm of the surpluses or the shortages of water in parrticular. It expresses the difference between the sum of the pluviometry and that of the Potential Evapotranspiration (PET) and when it is positive it is equal to the disposable surplus for the refill in water of the ground and for the flow (Sutcliffe and Piper, 1986 quoted by Vissin, 2001, Houndénou, 1999). It also allowed us to highlight the evolution of the climate through the rainy contributions and the losses by evaporation. PET is defined as the climate demand in steam. Thus:

- *If P - PET > 0, then the balance is surplus;*
- *If P - PET < 0, then the balance has a deficit;*
- *If P - PET = 0, then the balance is at fair value.*

The Climate balance assessment was often used, in particular in a regional study of the hydroelectric resources in West Africa (Thomson, 1985; Olivry, 1993; Le Barbé *et al.* or still in a study of the hydrological balance assessment in Guinea, in Togo-Benin (Sucliffe and Piper, 1986) and in Benin (Vissin, 2007). It was calculated from the average values of P and PET of the whole dock between 1965 and 2010.
Figure 6 represents the evolution of the climate balance assessment on at ten-day scale scale in Savè over the period between 1965 and 2010.

The analysis of figure 6 revealed two (02) great stages:

- The rainy season (BC > 0): from the second tenth of April till the third tenth of July; from the second tenth of September till the second tenth of October;
- The dry season (BC< 0): from the first tenth of January to the tenth of April, from the third tenth of

July to the first tenth of September, from the second tenth of October to the third tenth of December.

For Franquin (1969), the climate balance assessment allows to divide the year in successive bioclimate periods corresponding to periods of vegetative development as follows:

The period is dry when the curve of precipitation is below half of that of PET (P < ½ PET);

- The period is wet when the curve of half of Potential Evapotranspiration (½ PET) takes place under that of the precipitation;
- The period is extremely wet when the curve of PET passes under that of the precipitation.

Figure 7 shows the evolution of the climate diagram in Savè between 1965 and 2010.

The analysis of the figure 7 revealed that:

- The wet period (WP) extends from the middle of March till the end of October;
- The extremely wet period (EWP) from May till the beginning of October;
- The dry period (DP), from the end of October till March.

The alternation of dry and wet periods allows to theoretically distinguish four (04) seasons distributed as follows:

- The great rainy season: from March to July;
- The small dry season: from July to September;
- The small rainy season: from September to November;
- The great dry season: from November to March.

This distribution of rains determines the agricultural functions according to which months are dry or wet. Thus:

The dry months correspond to the period of "rest" for the farmers;

- The pre-humid months correspond to the period of cultivation and sowing;
- The wet months correspond to the period of growth of crops;
- The post--wet months correspond to the period of maturity of crops and harvest.

However, the large seasonal variability influences this distribution, which does not allow us to always observe the same distribution. This can expose the cultures to a high vulnerability and to a significant decrease in the yield

Discussion

The results showed that there was a very large variability of the rainfall from one station to another and that this remarkable variation of the precipitation constitutes a disruptive factor of the agricultural activities. As for the temperature, the calculated monthly mean values, showed a variation between 25 and 30.5°C. The changes in the insolation in Savè between 1965 and 2010 revealed that the annual average duration of the insolation in the study area was of 1740 hours with a monthly value of 289 hours. As for the climate balance assessment, the results revealed the occurrence of two (02) great seasons which are the rainy season and the dry season. The climate diagram of Savè between 1965 and 2010 showed alternations of dry and wet periods. These results are similar to those of Afouda (1990, 2009), Yabi *et al.* (2012) who reported for the Municipality of Natitingou an average pluviometric height higher than 1200 mm distributed on 90 days, and situated it among the most humid regions in Benin. Still, the temporal distribution of this rain height is very contrasted and cannot favour agricultural activities. Also, the climate balance assessment of Natitingou indicates that five (5) months (May-September) are openly wet; which, limits the producers to a single agricultural season in spite of the relatively important annual pluviometry.

Akognongbe *et al.* (2012) reported a unique modal regime and a variable climate balance in Parakou between 1965 and 2005 except that they put these climate parameters in connection with hydrodynamic risks. On the other hand, Ahamide *et al.* (2012) in the study of the potentialities and the constraints of sustainable development of the flooded plain of Agbobada in Municipality of Athièmé reported a pluviometric bimodal regime favourable to the agricultural seasons.

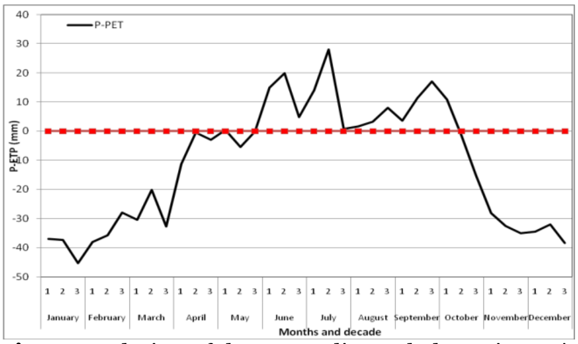

Fig. 6. Evolution of the mean climate balance in Savè between 1965-2010.

Source: Processing of ASECNA data, 2013.

These results are also in accordance with those of GIEC (2007), who asserts that the future impacts of the climate change on the agriculture in west Africa are the decrease of the surface of farming land, and that the climate variability is thus a constraint in the development of agriculture, the farmers thus have to develop strategies to mitigate the effects as they cannot eradicate the phenomenon. Results recorded in Dassa-Zoumé and Glazoué are also confirmed by Koumassi *et al.* (2012), who reported that various inter-annual variations of the precipitation (1965-2009) and the temperatures (1979-2007) especially the increase of the temperatures from 1995s have serious consequences on the agricultural activities in the water dock of the low valley of Mono.

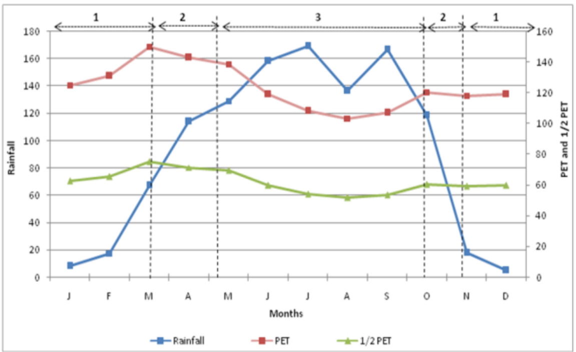

Fig. 7. Climate diagram of Savè between 1965 and 2010.

Source: Processing of ASECNA data, 2013.

Ogouwalé (2001) also discovered that agriculture in the sloping dock of Zou essentially remains pluvial. Therefore, it undergoes the repercussions of the variability of the climate, in particular the precipitation, the temperatures, etc. Additionally, Boko (1988) showed that the climate fluctuations and the demographic growth thus represent major constraints for the agricultural development and contribute to the dynamics of the practices of the various ecosystems in Benin.

Photo 1a. Corn field in hydric deficit in Kèrè (Dassa-Zoumè)

by: Kadjegbin, June 2013.

Photo 1b. Corn field in hydric deficit in Adourékoman 1 (Glazoué)

by: Kadjegbin, June 2013.

For Wokou (2014), the sloping dock of Zou is characterized by a climate variation during these last four decades. This variability is marked by a delay in the starting of rains, a decrease of the total pluviometries, a reduction of the duration of small rainy season, a reduction of the number of rainy days, an increase in the temperatures of about 0.9 °C referring to the period between 1971-2010, a decrease in the annual total pluviometries, in particular during 1970s and 1980, and seasonal fluctuations which disrupted agricultural activities.

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