

Article

# Recent and Future Characteristics of Climatic Parameters and Cropping Seasons in the Bandama Valley District (Côte d'Ivoire)

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**Abstract:** The impact of climate variability on agriculture in Côte d'Ivoire requires updating climate information and assessing its effects on agricultural seasons. To this end, rainfall and temperature data covering the period 1971-2020 were analyzed, calibrated, and statistically validated using absolute and relative deviations, Pearson's correlation ( $R^2$ ), and RMSE. Potential evapotranspiration requirements were estimated using the Thornthwaite method, and Nicholson indices were calculated. Climate projections for 2050 and 2100 according to the RCP 4.5 and 8.5 scenarios were established, while geostatistical methods based on the semivariogram were used to spatialize the data and obtain reliable spatial references. The results reveal interannual variability in precipitation with a general downward trend and an average increase in temperatures until 2010, followed by stabilization around 26°C. According to scenarios RCP 4.5 and 8.5, monthly temperatures in Bouaké could increase by 0.88 to 6.79°C by 2050-2100, while annual precipitation is expected to decrease slightly (by 0.9 to 1.71 mm/year) while exhibiting increased variability. Although the impact on the length of growing seasons is relatively small, rising temperatures and unstable rainfall patterns underscore the need to promote agricultural practices that are resilient to climate change.

**Keywords:** climate change, growing season, RCP scenario, Bandama valley district, Côte d'Ivoire

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## 1. Introduction

Climate change has significant negative impacts on agriculture in West and Central Africa, leading to major yield reductions in both the near and far future (Alimagham et al. 2024). In West Africa, particularly in Côte d'Ivoire, climate variability is reflected in pronounced fluctuations in key parameters such as rainfall and temperature (Kouman et al., 2022). These changes are reflected in a downward trend in precipitation, a rise in average temperatures, and disruption to agricultural seasons (Kouassi et al., 2022). However, climate remains a major determinant of agricultural production and has a significant impact on the distribution of farming activities. Local communities perceive these changes as direct threats to agricultural yields and, consequently, to household



and Malians). Despite pockets of industrialization (particularly agro-industries located in Bouaké and Katiola) and public measures aimed at diversifying the economy, agriculture remains the main activity of the population (Koffi et al., 2019). Unfortunately, this agriculture remains dependent on environmental conditions (Timité et al., 2022).

## 2.2. Study Data

### 2.2.1. Observation Data and Choice of Analysis Period

The rainfall data used come from the database of the National Meteorological Directorate (DMN) of Côte d'Ivoire located within the Airport and Meteorological Operations and Development Company (SODEXAM) and the Central Laboratory, Soils, Water and Plants (LCSEP) of the National Agricultural Research Center (CNRA). The choice of stations was guided on the one hand by the availability and quality of chronological data and on the other hand by considering their representative character of the entire study area. In doing so, data from three rainfall stations (Béoumi, Dabakala and Niakaramadougou) and a synoptic station were selected over the period from 1971 to 2020 for the analysis. Indeed, since the objective of this study is not to carry out a diachronic study, the application of the Pettitt test made it possible to choose the year 1971 as the starting point of the observations. This non-parametric test revealed breaks in the series around the 1970s (1967 for Béoumi, 1968 for Niakara, 1970 for Dabakala and 1972 for Bouaké), periods also identified in non-Saharan West Africa by Gautier et al. (1998). Also, temperature data from the four (04) stations mentioned above were used. They were acquired over the same period.

To fill in the gaps in the time series, land surface temperature (LST) data were extracted from satellite images from NASA's POWER (Prediction of Worldwide Energy Resources) platform (<https://power.larc.nasa.gov/>). The data from the virtual station grid were calibrated and validated using the Bouaké station, chosen as a reference for the completeness of its temperature series. The analysis revealed a systematic bias in the satellite values, overestimating temperatures by an average of 2.8°C. The formula used is as follows:

$$b = v' - v \quad (1)$$

Where: b = biases observed in the series:

v' = value extracted from satellite imagery; and

v = observed value.

This biased data was corrected by a statistical adjustment, and the calibrated data was then compared to the Bouaké observations using the correlation coefficient ( $R^2$ ) and the root mean square error (RMSE). The formula used to calculate the root means square error is as follows:

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (a' - a)^2} \quad (2)$$

Where a = predicted value and

a = observed value

The results showed a strong correlation ( $R^2 > 0.7$ ) and a significant reduction in discrepancies, confirming the reliability of the adjustment. This approach was then applied to neighboring stations lacking complete measurements, ensuring series consistent with ground observations.

### 2.2.2. Climate Projection Data

Since the late 1990s, publications on climate change have multiplied, revealing growing concern about the future of the climate (Masson-Delmotte, 2024). To this end, climate models through scenarios (SRES and RCP) have been developed considering the new context of global development, particularly the evolution of greenhouse gas concentrations.

For this study, the RCP 4.5 and RCP 8.5 scenarios were adopted primarily because of their widespread use in climate projections for West Africa and because they provide contrasting emissions trajectories. Second, the RCP 4.5 scenario reflects a stabilization scenario with mitigation policies, while the RCP 8.5 scenario represents a high-emission trajectory. Finally, combining them allows us to capture a wide range of plausible future climates, ranging from moderate to extreme conditions, thus enabling a robust assessment of the system's vulnerability (Gyamfi et al., 2024; Amichiatchi et al., 2024). The simulated and projected data concern average precipitation, minimum and maximum temperatures at monthly and annual time steps over a chronological series from 1971 to 2020. They were provided by the Coupled Model Intercomparison Project, CMIP5 (Coupled Model Intercomparison Project, version 5). It is a web interface that stores and manages queries in a large suite of climate observation data as well as future climate projections downloadable online: <http://cip.csag.uct.ac.za>.

### 2.3. Analysis Methods

#### 2.3.1. Interannual Variability of Precipitation

This analysis highlighted periods of excess and deficit rainfall on a spatio-temporal scale. The evolution of precipitation was characterized by the method of calculating reduced centered indices (Nicholson Index). This index allows us to follow the sequential evolution of rainfall. It is the ratio of the difference between the annual precipitation height at station  $i$  and the average annual precipitation height 1 to the standard deviation over the given period. These annual rainfall indices are calculated from the formula proposed by Nicholson et al. (1997):

$$I_i = \frac{X_i - \bar{X}}{\sigma}, \quad (3)$$

Where:

- $I_i$  = Rainfall index of year  $i$  or Nicholson Index.
- $X_i$  = Annual rainfall of year  $i$ ;
- $\bar{X}$  = Interannual average rainfall over the study period.
- $\sigma$  = Value of the standard deviation of rainfall over the study period.

The results of the calculated indices were classified according to the characteristics proposed by Faye et al. (2015).

**Table 1.** Classification of Humidity or Drought According to the Values of the Nicholson Indices Source: Faye et al. (2015)

Nicholson Index Class (I)	Degree of Drought/Humidity
$I > 2$	Extreme humidity
$1 < I < 2$	Strong Humidity
$0 < I < 1$	Moderate humidity
$-1 < I < 0$	Moderate drought
$-2 < I < -1$	Strong Drought
$I < -2$	Extreme drought

According to Kanga et al. (2018), negative indices indicate a downward trend while a positive index indicates an upward trend compared to the normal represented by the value 0. Thus, to have a better observation of interannual fluctuations, moving average curves were used.

### 2.3.2. Determination of Growing Seasons

Three methods are commonly used to determine agricultural seasons in tropical regions. The first is Franquin's method, which identifies seasonal segments by cross-referencing precipitation and potential evapotranspiration curves (Gnangouin et al., 2023). The second, proposed by Gausson, is based on the relationship  $P = 2T$  and allows for climate classification using ombrothermic indices of aridity or humidity. Finally, the third method is based on the analysis of the temporal organization of seasonal accumulations, in particular the start and end dates of the rainy season, as well as the duration of wet periods (Félicien et al., 2020). In this study, Franquin's method was preferred because of its simplicity of application and its high agroclimatic relevance. By providing a clear reading of growing seasons based on basic climate data, it is a reliable reference for seasonal analysis in tropical areas. It is therefore particularly suitable for agroclimatic studies, agricultural activity planning, and climate change impact assessment. It is also the most widely used method in intertropical regions.

This crossing makes it possible to determine the remarkable climatic events which define the pre-humid, humid and post-humid periods of the growing seasons (Diomande et al., 2016). The growing season begins with rainfall greater than  $PET/2$  and ends when it is less than  $PET/2$ . The Franquin method allows us to propose a cropping calendar based on rainy and humid periods as delimited:

- Pre-humid period: A2 B1 with  $P < PET$ , so Actual Evapotranspiration (AET)  $< PET$ .
- Humid period: B1 B2 with  $P > PET$ , so AET = PET.
- Post-humid period: B2 C2 with  $P < PET$ , so AET  $< PET$ .

PET was calculated by the Thornthwaite method (1948, cited by Mutondo, 2018). The Thornthwaite method (1948) was chosen for calculating potential evapotranspiration (PET) because of its simplicity and the limited availability of climate data. This empirical approach requires only the average monthly temperature and latitude, making it particularly suitable for contexts where meteorological data are limited. Unlike more complex methods such as Penman-Monteith, which require accurate measurements of solar radiation, relative humidity, and wind speed, the Thornthwaite method remains applicable in the absence of these parameters (Kumar et al., 1987; Nicholson et al., 1997). PET was calculated using the following formula:

$$PET = 16 \left( \frac{10 \times T}{I} \right)^a \times \frac{N}{12} \times \frac{L}{30} \quad (4)$$

With:

- T = Average annual temperature (°C)
- I = Annual thermal index given by the sum of the indices

$$i = \left( \frac{T}{5} \right)^{1.54} \quad (6)$$

a = empirical coefficient dependent on I, with:

$$a = (6,75 \times 10^{-7}) \times I^3 - (7,71 \times 10^{-5}) \times I^2 + (1,79 \times 10^{-2}) \times I + 0,49239 \quad (5)$$

- N = Average daily sunshine duration for the month (in hours) based on latitude
- L is the length of the month (in days)

The annual thermal index I is obtained by summing the indices  $i$  for each month where  $T > 0$ . The method is valid for positive monthly temperatures, for  $T \leq 0$ , the ETP is null.

Also, within the framework of the RCP analyses, absolute and relative standard deviations were calculated, and Pearson correlation tests were performed at the 0.01% level.

### 2.3.3. Data modeling and geostatistical analysis methods

Climate analyses for 2050 and 2100 in Bouaké were carried out using Global Climate Models (GCM) or Coupled General Circulation Models (CGCM) under RCP4.5 and RCP8.5 scenarios, in accordance with the work of Soro et al. (2017). The annual cycle of average temperatures and rainfall was simulated using eleven models from CIMP5.

Statistical analyses focused on measures of central tendency (mean) and dispersion (standard deviation) to characterize the data (observed data and estimated data) and explore the relationships between the variables studied. Measures of central tendency (mean) were used to assess variations between temperature and precipitation data (projected data), while standard deviations, both absolute and relative, were used to assess the accuracy and internal variability of the measurement series. These statistical analyses made it possible to assess the stability and representativeness of the data at a significant level of 1% ( $p < 0.01$ ). The relationships between variables were explored using Pearson's correlation coefficient ( $r$ ). According to Parey (2013), considering both mean and variance trends improves the modeling of extreme events in climate projections.

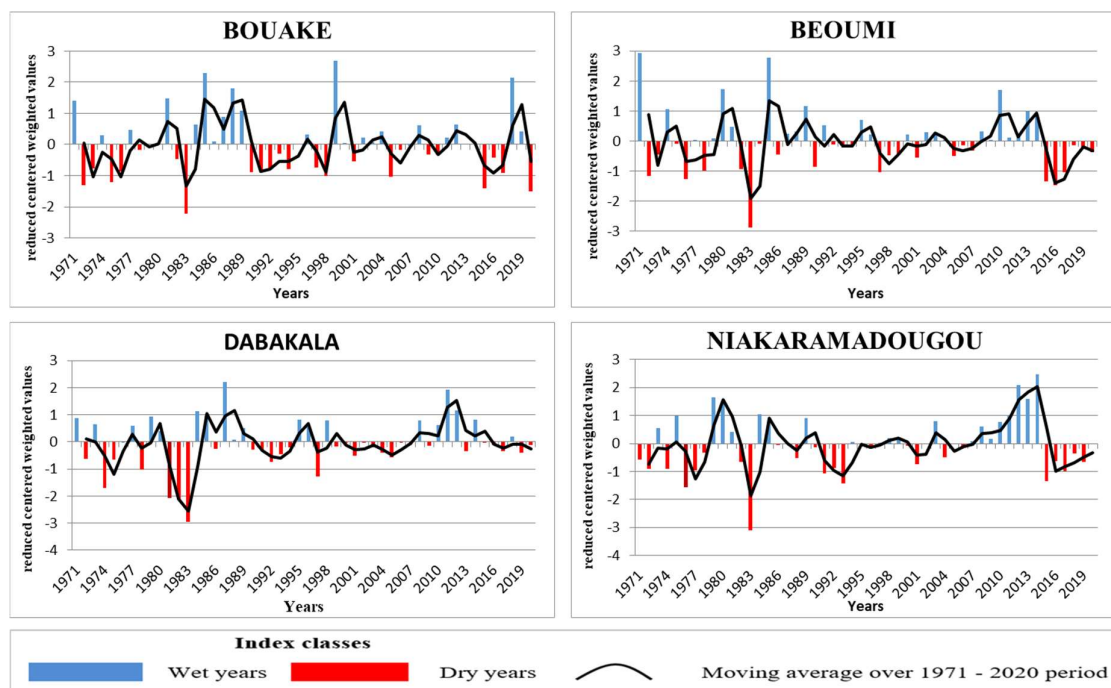
For the spatial analysis of rainfall and temperature data, a geostatistical method based on the semivariogram (kriging) was used to assess the similarity of nearby values (spatial autocorrelation) and its decrease with distance. This technique makes it possible to estimate missing values based on known surrounding observations, weighing them according to their spatio-temporal correlation.

### 3. Results

#### 3.1. Current State of Climate and Growing Seasons in the Bandama Valley District

##### 3.1.1. Interannual Variability Alternating Between Dry and Wet

The interannual rainfall variability in the Bandama Valley District is illustrated by figure 2. All stations show alternations between dry and wet periods punctuated by rainfall extremes. The year 1983 was extremely dry in all stations (index < 2). On the other hand, the years 1985, 1999 and 2018 in Bouaké, 1971 and 1985 in Béoumi, 1997 in Dabakala, 2012 and 2014 in Niakaramandougou were extremely wet (Index > 2). In 50 years of rainfall measurements, 22 were deficient (moderate, strong or extreme drought) in Bouaké against 29 in Béoumi, 30 in Dabakala and 25 in Niakaramandougou. Nevertheless, the stations tend towards a rainfall deficit since the years 2019 for Bouaké and 2015 for Béoumi, Dabakala and Niakaramandougou. Those of Béoumi and Niakaramandougou are the most marked.



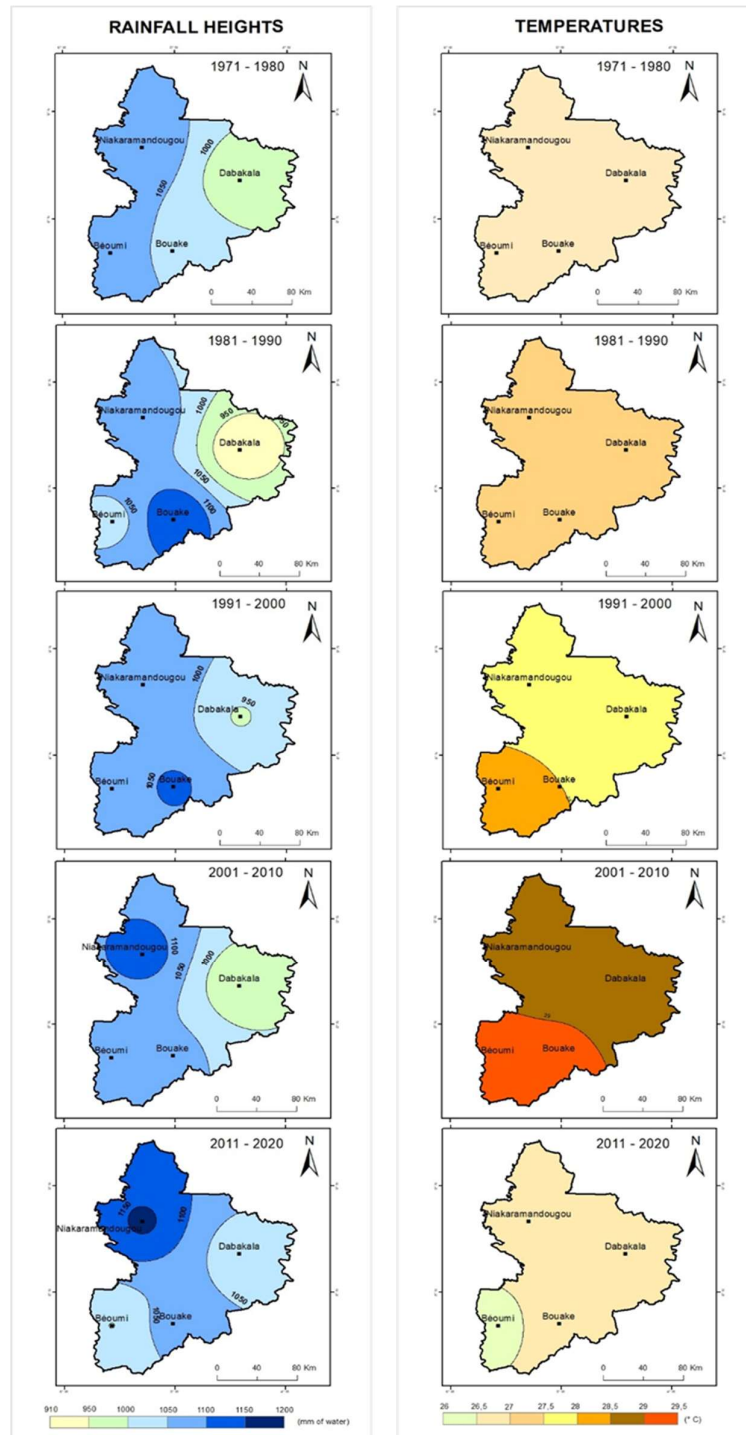
**Figure 2.** Interannual rainfall variation according to the Nicholson Index (1971-2020) (Source: Results from the processing of rainfall data)

### 3.1.2. Increase in Rainfall Amounts from the Decade of 2001-2010 and Decrease in Average Temperatures

The maps in Figure 3 describe the evolution of the classes delimited by the isohyet curves ranging from 900 to 1200 mm and those of temperatures, evolving between 26 and 29 °C. Over the past five decades, annual rainfall has been marked by a recovery of precipitation amounts from the period 2001-2010 while temperatures have followed a generalized decline during the period 2010-2020. In general (over 50 years), the spatial distribution of rainfall amounts is marked by an average increase of 4.57% in rainfall amounts following an east/west gradient, with peak precipitation in the northwest (1,098 mm) and south (1,062 mm). At the level of temperatures, they varied between 26.03 and 26.48 °C on average per year with low annual amplitudes (between 1.5 and 3.8 °C). The highest temperature values are observed beyond 8° North latitude, with maximum values close to 30 °C. Below (Béoumi and Bouaké) the amplitudes are rather weak, and the averages very little.

The decade of 1971-1980 is quite regular in the distribution pattern of rainfall with a homogeneous distribution of temperatures (between 26 and 26.9 °C). During this period, the Bandama Valley District is limited by the 1100 mm isohyet on the western half (between the longitudes of Bouaké and Béoumi) and 950 mm to the East (at the latitude of Dabakala). Between these two zones (East and West), the area is watered by rainfall between 1000 and 1050 mm. The decade of 1981-1990, for its part, is marked by a decrease in rainfall amounts following the West-East gradient, while temperatures have increased (27-27.5 °C) while remaining homogeneous in their distributions. The Dabakala area is the driest while the highest amounts of rain are observed in Bouaké. During this decade, the Bandama Valley District recorded its lowest rainfall levels, particularly in Niakaramadougou (1044 mm) and Béoumi (1055 mm). This decrease was accompanied by an average temperature increase of approximately 0.5°C in the southern part of the district. The area with rainfall less than 1000 mm extends a little more towards the Center while 3/4 of the area is covered by rainfall from 1000 to 1050 mm. There is also a large decrease in the area covered by isohyets from 900 to 950 mm. Only the Bouaké rainfall station records rainfall greater than 1050 mm (between 1050 and 1100 mm). The decrease in rainfall observed from 1971 to 2000 is stopped during the decade 2001-2010. The area with rainfall less than 1000 mm experienced during this period a slight regression and is still located around Dabakala. On the other hand, temperatures are at their extremes (28-29 °C). Finally, the decade 2011-2020 is only the continuation of the wet period of the previous decade. The 1000 mm isohyet has completely disappeared from the area. The rainfall stations above the 8th parallel have experienced an increase of 3 to 7% of their rainfall. Below, the amounts of rain have decreased by 6% between the decade 2001-2010 and that 2011-2020 at the Béoumi station.

For five decades (1971 to 2010), the East of the Bandama Valley District was marked by low rainfall values (less than or equal to 1000 mm). The decade (2010-2020) was the wettest in the district (except for Béoumi) and that of 1981-1990 was the wettest in Bouaké and the driest in Dabakala. Furthermore, temperature trends show an upward trend, estimated at an average of +4.4% until 2010, followed by a stabilization phase around 26°C during the decade 2010-2020, reflecting a possible thermal plateau in regional climate dynamics.



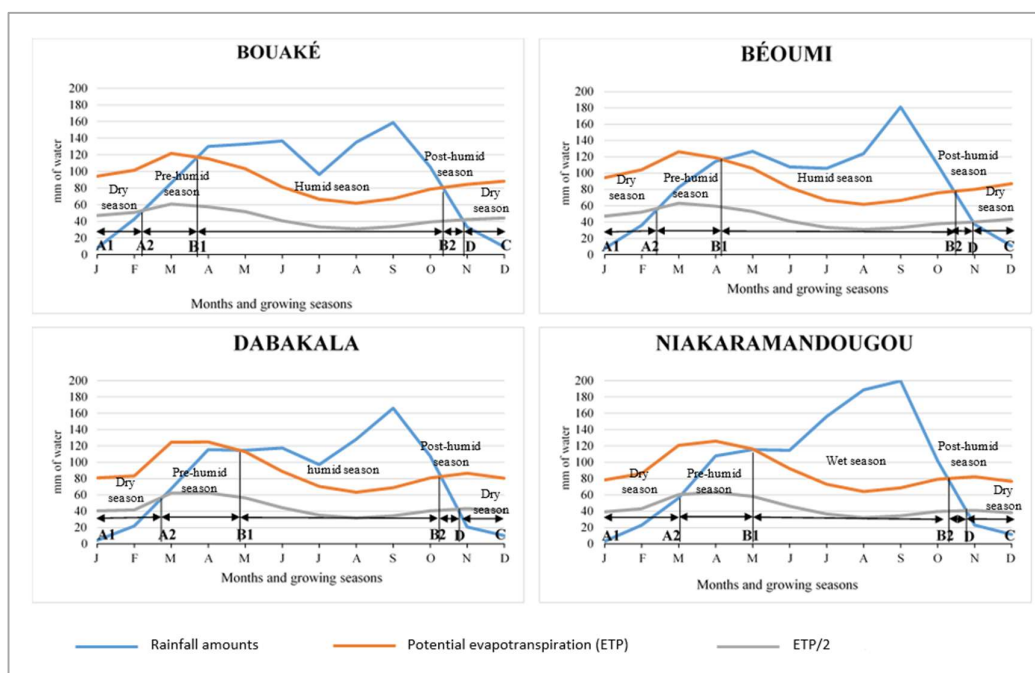
**Figure 3.** Decadal variations in average rainfall and temperature (1971-2020) (Source: Results from the processing of climate data)

### 3.1.3. Characteristics of Current Growing Seasons

The identified growing seasons include three periods, namely the pre-humid, humid, and post-humid periods (Figure 4).

In Bouaké and Béoumi, the pre-humid period begins in February (2nd decade) and ends in April (1st and 2nd decade respectively for Bouaké and Béoumi). The plots remain slightly wet during this long

period (02 to 03 months) because of the irregularity and insufficiency of the rain. The humid period begins in April (2nd decade) when the wilting of plants begins to decrease and ends in October (3rd decade). This long humid period (06 months) characterizes sufficient rainfall to moisten the soil. However, the soil becomes dry from the post-humid period (B2D) as indicated by the decreasing trend of the rainfall curve. The dry period extends from the 3rd decade of October to the 2nd decade of February and indicates a recession of rain. In Dabakala and Niakaramandougou, the arrangement of the agroclimatic periods mentioned above remains practically the same. Unlike the stations in the South of the study area, the dry periods are longer in the North and last 04 months on average (from the 1st decade of November to the last decade of March). Also, the pre-humid periods are more extensive there compared to the South (between the 2nd and 3rd decade of March to the 2nd or 3rd decade of May). Thus, the positions of the curves highlight the annual variability of rains and vegetative periods.



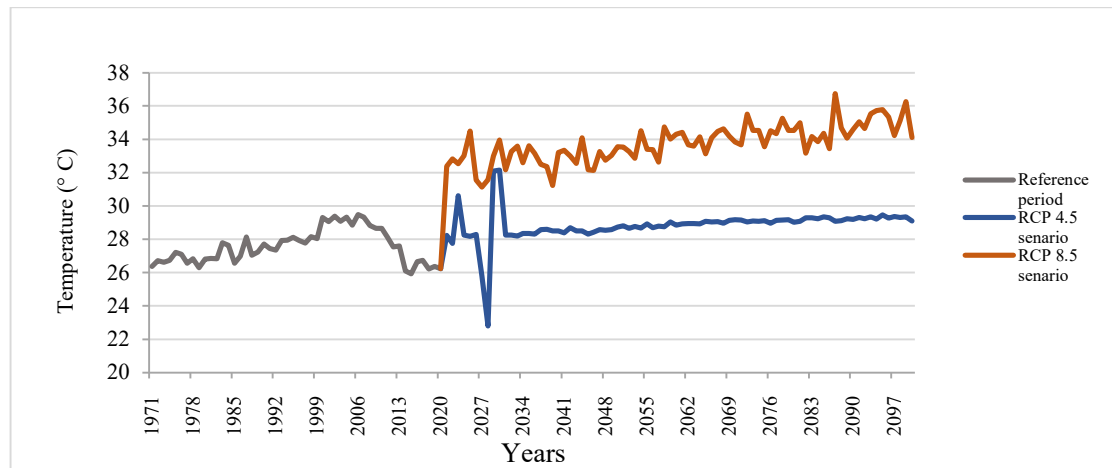
**Figure 4.** Curves for determining growing seasons over the period from 1971 to 2020  
 Source: Results from the processing of rainfall and temperature data

### 3.2. Climate Outlook and Probable Agricultural Seasons According to RCP Scenarios

#### 3.2.1. Climate Outlook at the 2050 and 2100 Horizons

The thermal average derived from the multi-model overestimates reality (comparison between observed values and simulated values), despite the scenarios. The standard deviations are close in value (0.38 for the RCP 8.5 scenario and 0.32 for the RCP 4.5 scenario), and the correlation coefficients in the case of scenario RCP 8.5 ( $r = 0.54$ ) and scenario RCP 4.5 ( $r = 0.52$ ) are practically identical. The p-values also indicate a significant relationship between the observed and simulated data at the 99% confidence level. So, the multi-model does a good job of simulating the temperature data at the Bouaké station according to the two scenarios chosen. However, the simulation of temperature data according to the RCP 8.5 scenario is better. The evolution of the average monthly temperature in Bouaké, considering the reference period, shows positive deviations according to the RCP 8.5 and 4.5 scenarios. The rise in monthly temperatures is on average 5.24 °C and 6.79 °C for RCP 4.8 respectively at the 2050 and 2100 horizons. This increase is relatively smaller for RCP 4.5 (0.88 °C and 1.52 °C respectively at the 2050 and 2100 horizons). The highest temperature increase is noticeable in September and July (respectively 23.43% at the 2050 horizon and 30.35% at the 2100 horizon) for the

RCP 8.5 scenario. As for the RCP 4.5 scenario, the months of January and August are the hottest (with an increase of 3.6% at the 2050 horizon and 6.16% at the 2100 horizon). This temporal evolution of temperatures also reflects an irregularity of the latter over the years as shown in Figure 5. From 2030, a relative stability of temperatures is observed according to the RCP 4.5 scenario.



**Figure 5.** Evolution of projected average annual temperatures at the 2100 horizon according to the RCP 8.5 and RCP 4.5 scenarios (Source: Results from the processing of thermal data)

The annual average rainfall intensities from the multi-model are lower than reality, even though the absolute and relative differences between the observed and simulated data are quite high. The absolute differences are greater than 100 mm in all cases. The relative difference for the RCP 4.5 scenario (-10.86) is significantly lower than that for the RCP 8.5 scenario (-9.93). The correlation coefficients in the case of the RCP 8.5 scenario ( $r = 0.255$ ) and the RCP 4.5 scenario ( $r = 0.256$ ) remain low overall. On the other hand, p-values below 0.01 indicate a significant link between the observed and simulated rainfall data at a confidence level of 99%. Therefore, the multi-model accurately simulates rainfall data at the Bouaké station. However, in view of the differences (absolute and relative), rainfall data are better simulated according to the RCP 8.5 scenario. The evolution of average monthly and annual rainfall, considering the reference period (1971 to 2020), also shows positive and negative deviations according to the RCP 8.5 and 4.5 scenarios. The decrease in the amount of annual rain is not significant enough. In terms of absolute deviation, it decreases by 1.71 and 1.28 mm at the 2050 and 2100 horizons according to the RCP 8.5 scenario. However, it varies by 0.41 and -0.9 mm over the same periods according to the RCP 4.5 scenario. Considering the relative deviations, the month of January is the month that becomes drier at the 2050 horizon according to RCP 8.5. That of February experiences an evolution of 21% of rainfall values over the same horizon according to the RCP 4.5 scenario. At the 2100 horizon, the month of December becomes increasingly rainy with an increase in rainfall of 34.43% and 14.16% respectively for the RCP 8.5 and 4.5 scenarios. The resulting interannual variability is presented in Figure 6.

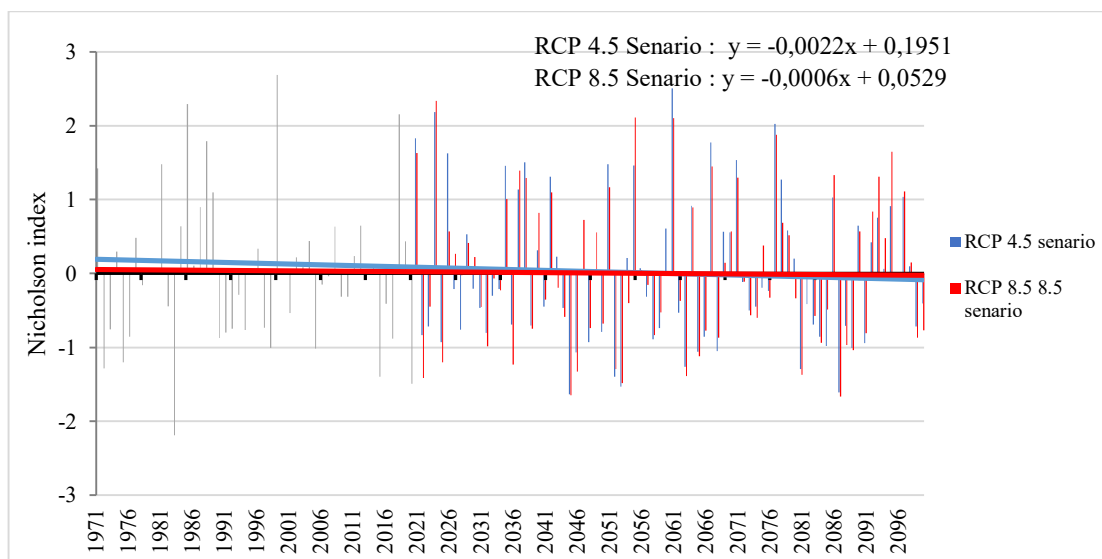


Figure 6. Rainfall anomalies at the 2100 horizon according to the RCP 8.5 and 4.5 scenarios (Source: Results from the processing of rainfall data)

### 3.2.2. Probable Unchanged Growing Seasons

In view of the climate projections according to the RCP 4.5 and 8.5 scenarios in the South of the Bandama Valley District (Bouaké), climate variations will have little effect on the durations of growing seasons. The annual spread of growing seasons, identified from the projection data (RCP 4.5 and 8.5), are relatively identical to those observed between 1971 and 2020 and those, whatever the climate scenario (Figure 7). Indeed, the dry periods remain substantially the same and last four (04) months on average (between November and February) while the pre-humid and post-humid periods last respectively two (02) and one (01) month on average. The humid period, for its part, begins between the end of March and the beginning of April to end during the first decade of October.

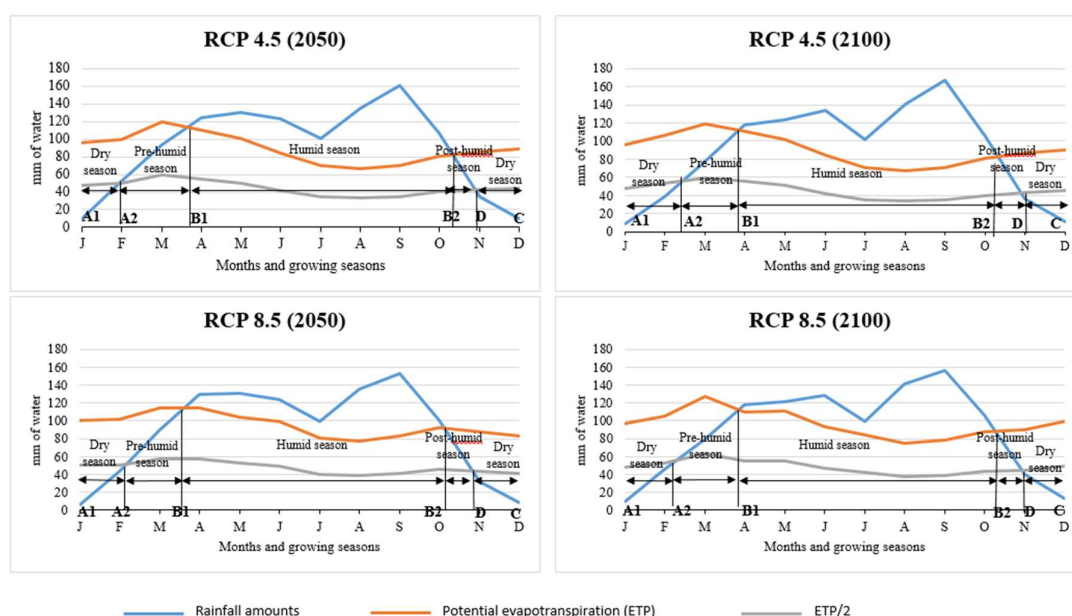


Figure 7. Evolution of agricultural seasons at the 2050 and 2100 horizons according to the RCP 4.5 and 8.5 scenarios (Source: Results from the processing of rainfall data)

## 4. Discussion

### 4.1. Towards a Resumption of Rainfall in West African Regions

The climate of the Bandama Valley District has undergone significant changes over the past four decades. Like the rest of the country, this area experienced a notable decline in rainfall between 1971 and 2000, with an estimated decrease of between 4% and 10%, depending on the east-west gradient. While the south of the country remains relatively stable, receiving an average of 1,050 mm of rain per year, regions north of the 8th parallel have seen a slight increase in annual rainfall, ranging from +0.3% to +7%. Since 2001, this moderate increase in precipitations has been accompanied by a drop in temperatures and an increase in relative humidity, which were particularly marked during the decade 2011-2020. Since 2015, a reverse trend has been observed in the eastern part of the district, particularly in the departments of Niakaramandougou and Béoumi, where rainfall has markedly decreased (indices < 0). In contrast, temperatures have remained relatively stable, averaging around 26 °C, despite the decline in rainfall during the 2011-2020 decade. Average annual temperatures have consistently remained above 20 °C, a trend also reported by Brou (2005) in his work on Côte d'Ivoire. The increase in annual rainfall since the 2000s can be explained in part by an increase in extreme rainfall observed during the decade. This was noted by Descroix et al. (2013) in their studies on recent rainfall trends in West Africa. According to these authors, for nearly twenty years, the subregion has been experiencing a gradual return of total annual rainfall, with an upward trend in average values. This phenomenon could signal the beginning of a change in rainfall trends. However, rainfall amounts are still lower than those observed in the 1950s and early 1960s. For their part, Sarr et al. (2015), in their study on agroclimatic risks related to precipitation in Niger, highlight a recovery in rainfall conditions, with an upward movement of the 400 and 300 mm isohyets, which are shifting several kilometers from the south to the north of the country. A similar observation concerning the recovery of rainfall in West Sahelian Africa was also made by Nouaceur (2020). In his study on the annual rainfall signal using the graphical matrix (MGCTI), he observed a moderate but progressive change in annual rainfall levels.

### 4.2. Agroclimatic Risks Induced by Probable Climate Variations

Climate projections based on emission scenarios (RCPs) indicate that between 2050 and 2100, the length of growing seasons will remain broadly like that observed during the historical period 1971-2020. However, these projections highlight significant changes in climate parameters, in particular a continuous rise in average annual temperatures and a change in rainfall patterns. In Bouaké, simulations from the global climate model (GCM) predict an average temperature increase of around 0.5°C ( $\pm 0.2^\circ\text{C}$ ) per decade by 2100, with varying intensities depending on emission trajectories (RCP 4.5 and RCP 8.5). About precipitation, trends diverge depending on the scenario: an increase under RCP 8.5, particularly over the period 2051-2100, and a general decrease under RCP 4.5. These results are consistent with Soro et al. (2017), who project a stronger temperature increase in the Bandama basin under RCP 8.5 than RCP 4.5, along with a relative increase in rainfall during the wet season, with contrasts expected to intensify over the long term. Similarly, Kouamé et al. (2014) estimates that annual temperatures could rise by 3 to 4.2°C, accompanied by an average increase in precipitation of 4.9% over the century. The impacts of these changes on the length of growing seasons appear to be limited, but their effects on agricultural productivity could be considerable. Analyzing useful precipitation between 1950 and 2000, Noufé et al. (2011) observes a ten-day reduction in the first growing season in western Côte d'Ivoire, while this duration remains stable in the east. It is in this context that Vodounou et al. (2016) point out that any change in climatic parameters directly affects the phenological stages of crops.

In this context, the adaptation of agricultural production systems appears essential. This involves the development and adoption of short-cycle varieties or varieties that are tolerant to heat and water deficit, the diversification of cropping systems to reduce the risk of losses, and the adjustment of agricultural calendars to better synchronize sowing with new rainfall conditions.

## 5. Conclusion

This study, based on the characterization of climate parameters, highlighted both current growing seasons (observed data) and those projected under different climate scenarios (RCP). The results show an increase in precipitation in the Bandama Valley District from the 2000s onwards, as well as a relative decrease in temperatures over the period 2011-2020. Projections from a multi-model ensemble, based on the RCP 4.5 and RCP 8.5 scenarios, indicate a marked upward trend in temperatures until 2100, associated with more contrasting rainfall patterns: an overall downward trend, but with significant interannual variations. However, these fluctuations appear to have a limited effect on the length of the agricultural seasons.

On the other hand, the main agroclimatic risks stem from the ability of crop varieties to adapt to changing conditions. Rising temperatures and increasingly irregular rainfall are major stress factors that could affect the productivity and stability of agricultural systems in the region. Therefore, supporting producers through research, extension services, and public policies is crucial to promoting the adoption of agricultural systems that are resilient to climate hazards (supplementary irrigation, rainwater harvesting, conservation practices and organic amendments).

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