

**Impact of local global warming on rainfall and annual cocoa water requirements in the regions of Loh-Djiboua and Goh in west-central Côte d'Ivoire**

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**SUMMARY**

**Aims:** To understand the role of the variability of rainfall totals and maximum interannual dry sequences in cocoa production in the Centre-West, one of the cocoa basins in Côte d'Ivoire, in order to propose technical routes better adapted to current rainfall conditions

**Study design:** Collection, analysis and processing of daily rainfall data collected by rain gauges at Divo and Gagnoa stations from 1946 to 2015.

**Place and duration of studies:** Divo Cocoa Research Station of the National Center for Agricultural Research, between January 2017 and June 2019.

**Methodology:** The rainfall regime of each locality was determined to assess the impact of ongoing rainfall changes on the seasonality of precipitation. The interannual variability of rainfall was studied from the reduced centred rainfall indices. The break years in the time series were detected at both stations from the KhronoStat software. Interannual rainfall totals were analysed for each station at the 1200 mm threshold, which is the minimum allowed for cocoa trees. The mean values of the maximum interannual dry sequences were determined using the Instat + Version 3.37 agrometeorological software and the probabilities of having maximum dry sequences exceeding 3 months were calculated.

**Results:** The rainfall regime in the area studied (west-central Côte d'Ivoire) has not been modified by the post-rupture rainfall recession as is the case in other parts of the country; it remains a bimodal system characterized by two rainy seasons and two dry seasons in the year. The Divo and Gagnoa regions have been facing a general recession in rainfall since 1966 in Gagnoa and 1972 in Divo. However, the locality of Gagnoa has experienced an increase in rainfall since 2000. Most of the rupture detection tests identified rainfall rupture dates identical to those indicated by the interannual variability revealed by the rainfall indices. Interannual rainfall totals after breaks are reduced compared to those before 1966 in Gagnoa and 1972 in Divo. This situation has led to an increase in the maximum interannual dry sequences in the departments.

**Conclusion:** Local climate change has created difficult post-rupture rainfall conditions for cocoa trees as their water needs are increasingly reduced, especially in Divo in Loh-Djiboua where the downward trend in rainfall has been continuous since 1972. In Gagnoa since the 2000s, there has been a new wet period that allows rainfall to adequately meet the cocoa tree's water needs.

*Keywords: Global warming, rainfall, cocoa water requirements, Central West Côte d'Ivoire*

**1. INTRODUCTION**

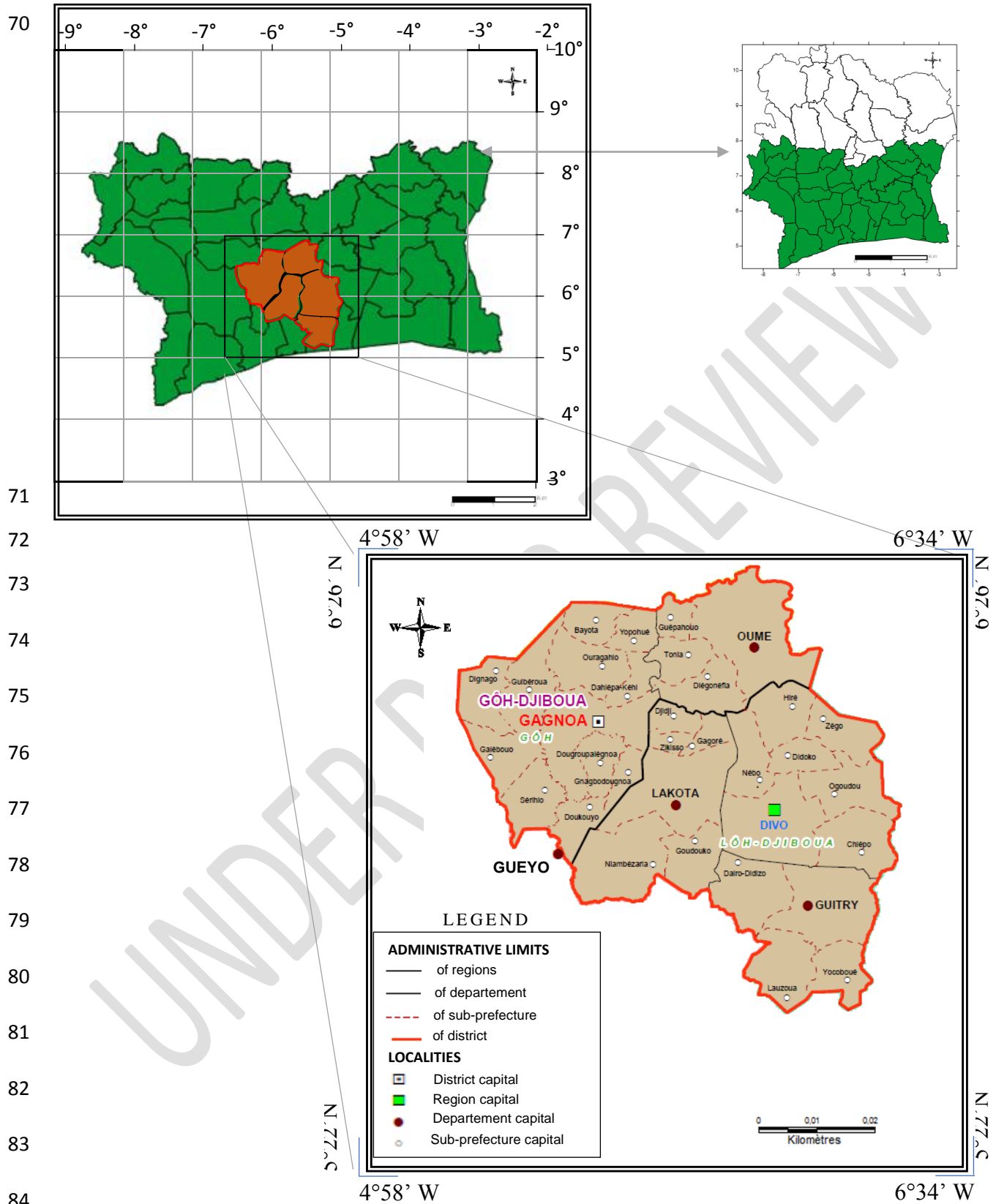
Since time immemorial, the climate has been constantly changing. But the new development model adopted by humanity with the advent of the industrial era has made man the main architect of current

21 climate change. And the recent history of climate characterized by the exceptional warming of the climate  
22 system is a clear illustration of this. The effects of this global warming on the planet, in relation to local  
23 microclimates, are felt in different ways. In West Africa, global warming is mainly reflected in a fairly  
24 significant decrease in annual rainfall with rainfall deficits in the order of 20% to 30% and decreases in river  
25 flows ([1], [2], [3], [4]). Côte d'Ivoire, due to its geographical location, is inevitably suffering from this  
26 widespread rainfall recession. Indeed, several specialists ([5], [6], [7], [8], [9], [10], [11], [12]) have shown  
27 that the decline in annual rainfall levels began in the north of the country before gradually spreading to the  
28 central and southern coasts. And since the early 1970s, this situation has worsened across the country.  
29 This climate variability has affected not only the precipitation regime, but also hydrological and plant  
30 resources [13]. The southern forest of Côte d'Ivoire, like the rest of the national territory, depends mainly on  
31 agricultural products both as a direct means of food and as a source of income. This dual importance of  
32 agriculture, which is typically rainfed in Côte d'Ivoire, makes households particularly vulnerable to changes  
33 in local rainfall. In the Central West, which is one of the main cocoa-producing regions in the country,  
34 rainfall instability does not always allow cocoa farmers to achieve the expected yields. This situation poses  
35 serious threats to the country's economy, which is mainly dependent on cocoa production. This study was  
36 therefore initiated in order to ensure the sustainability of cocoa production in this region, which represents  
37 the second cocoa loop in Côte d'Ivoire. It will enable the various actors in the cocoa sector to better  
38 understand the evolution of the essential rainfall factors in cocoa production, which despite recent work in  
39 the study area [14] remain relatively unknown.  
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## 42 2. METHODOLOGY

### 43 44 2.1 DESCRIPTION OF THE STUDY AREA

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46 The study was carried out in the Centre-West of Côte d'Ivoire, in the regions of Lôh-Djiboua and Gôh,  
47 whose respective chief towns are Divo and Gagnoa. It is located in the second cocoa loop (1960-1970)  
48 between latitudes 5°22' and 6°26' N and longitudes 4°58' and 6°34' W and covers an area of 10792 km<sup>2</sup>  
49 (Figure 1). These regions belong to the district of Gôh-Djiboua, which is located in the humid tropical zone  
50 [15] where rainfall fluctuates between 1200 and 1600 mm per year [16] and is divided into four seasons: a  
51 major rainy season from March to June, a small dry season in July and August, a small rainy season from  
52 mid-September to mid-November, and a major dry season from December to February. The average  
53 humidity of 85% is subject to strong seasonal variations. The average temperature is 27°C and varies  
54 annually between 19° and 33°C. The duration of annual exposure is about 1800 to 2000 hours. The  
55 predominant climax is the semi-deciduous dense rainforest. The soils are moderately to highly desaturated  
56 ferrallitic ([17], [18]). The humus horizon is thin, but rich in organic matter, weakly acidic and well structured  
57 under primary forest. These soils are suitable for perennial crops such as coffee and cocoa.  
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## 86 2.2. Data used and methods of analysis

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### 88 2.2.1. Data used

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90 To carry out this study we used daily rainfall data from Divo and Gagnoa over the period 1946-2015. The  
91 rainfall database used comes from the meteorological service of the Sustainable Soil Management and  
92 Water Management Programme of the Centre National de Recherche Agronomique (CNRA); but also from  
93 the historical database of the Office pour la Recherche Scientifique des Territoires d'Outre-Mer (ORSTOM),  
94 now the Institut de Recherche pour le Développement (IRD).

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### 97 2.2.2. Methods of analysis

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#### 99 2.2.2.1. Period selection, criticism and data filling

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101 The temporal window chosen for this study (70 years) has the advantage of having fairly homogeneous  
102 data with complete annual series, with the exception of certain years when some data are missing,  
103 particularly on the Divo station, where the incomplete data of 1946 were replaced by those of the Tiassalé  
104 station, only 60 km away. This recent and fairly long database provides objective and more representative  
105 trends of the current climatic conditions of the departments studied.

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#### 108 2.2.2.2. Characterization of the rainfall regime in the regions studied

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110 The analytical components used to characterize the rainfall regime mainly concern monthly and annual  
111 rainfall totals. These climatic variables make it possible to identify the rainfall trend in the study area and to  
112 highlight the interannual variability of precipitation.

113 For the characterization of the rainfall regime, the treatment consisted in calculating the monthly totals for  
114 each station in the area over the reference period (1946-2015).

115 The annual totals made it possible to study the quantities and rates of rainfall. They are calculated by the  
116 simple cumulation method:  $\sum_{i=1}^{12} x_i$  nor with nor = monthly values. The arithmetic mean  $\bar{X}$  was used to study  
117 rainfall patterns over the reference period. It is expressed as follows:  $\bar{X} = \frac{1}{n} \sum_{i=1}^n x_i$  with :  $x_i$  = monthly rainfall  
118 per year and  $n$  = number of years.

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#### 120 2.2.2.2.3 Reduced centred Lamb or Nicholson indices

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122 It is a method that was developed by Lamb [19] and adopted by [20]. The rainfall index is the ratio of the  
123 difference between the annual precipitation amount at station  $i$  and the average annual precipitation  
124 amount over the standard deviation of the period considered. It is a reduced centred variable that is used to  
125 study the interannual variability of rainy seasons. The annual rainfall indices are calculated according to the  
126 formula proposed by [20]:

$$I_i = \frac{X_i - \bar{X}}{\delta}$$

127 Where  $I_i$  = rainfall index for year  $i$

128  $X_i$  = Annual rainfall in year  $i$

129  $\bar{X}$  = Mean interannual rainfall over the reference period

130  $\delta$  = Value of the standard deviation of interannual rainfall over the reference period

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#### 132 2.2.2.3.1. Hanning low-pass filter of order 2

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134 A better observation of interannual fluctuations is achieved by eliminating seasonal variations. In  
135 this case, the annual rainfall totals are weighted using the following equations recommended by  
136 [21]:

$$X_{(t)} = 0.06x_{(t-2)} + 0.25x_{(t-1)} + 0.38x_{(t)} + 0.25x_{(t+1)} + 0.06x_{(t+2)} \text{ Pour } 3 \leq t \leq (n - 2)$$

137 Where:  $X(t)$  is the weighted total rainfall of the term  $t$ ,  $x(t-2)$  and  $x(t-1)$  are the total rainfall of the two terms  
138 immediately preceding the term  $t$ , and  $x(t+2)$  and  $x(t+1)$  are the total rainfall of the two terms immediately  
139 following the term  $t$ .

140 The weighted rainfall totals of the first two terms ( $X(1)$ ,  $X(2)$ ) and the last two terms ( $X(n-1)$ ,  $X(n)$ ) of the  
141 series are calculated using the following expressions ( $n$  being the size of the series):

$$142 X_{(1)} = 0.54x_{(1)} + 0.46x_{(2)}$$

$$143 X_{(2)} = 0.25x_{(1)} + 0.50x_{(2)} + 0.25x_{(3)}$$

$$144 X_{(n-1)} = 0.25x_{(n-2)} + 0.50x_{(n-1)} + 0.25x_{(n)}$$

$$145 X_{(n)} = 0.54x_{(n)} + 0.46x_{(n-1)}$$

146 The main trends are also highlighted by an affine regression line:  $y = ax + b$ ; it is obtained by calculating  
147 the slope ( $a$ ), which is a guiding coefficient :

148 If  $a > 0$ , we have an upward trend and if  $a < 0$ , we have a downward trend.

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#### 150 2.2.2.4. Methods for determining breaks within interannual rainfall series

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152 The "KhronoStat" software, designed by HydroSciences Montpellier and freely accessible on the SIEMEM  
153 website (<http://www.hydrosciences.org/spip.php>) [22] was used to detect possible breaks in time series. A  
154 break can be generally defined by a change in the probability law of the time series at a given time, most  
155 often unknown [6]. This program includes many specific tests of a change in the behaviour of the variable  
156 in the time series. The detection of breaks within time series required the application of a set of methods,  
157 including the Pettitt test [23], the Buishand "U" method [24], the Bayesian procedure of Lee and Heghinian  
158 [25] and the segmentation procedure [26]. It is at the end of the application of these various tests that a  
159 failure date detected by the majority of the tests was chosen.

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#### 161 2.2.2.5. Major rainfall factors in cocoa production

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163 The productivity of a cultivated cocoa tree necessarily requires regular growth, abundant flowering and  
164 fruiting as well as well-distributed foliar outbreaks throughout the year. To do this, it must be in favourable  
165 climatic conditions, obeying several criteria, the most important of which are as follows: (1) the annual  
166 rainfall amounts are between 1200 and 1500 mm [27] but a minimum annual threshold of 1200 mm is  
167 sufficient to consider its establishment in a region [28]; (2) the annual duration of the dry season is less  
168 than 3 months [20].

169 In this work, the maximum interannual dry sequences were determined using Instat+v.3.37 software. As  
170 well as the averages and percentiles from the descriptive statistical analysis. It should be recalled that a dry  
171 sequence is defined as the number of consecutive rain-free days with a height greater than the minimum  
172 value (1 mm) of the smallest of the classes of daily precipitation amounts proposed by the international  
173 standards defined by the World Meteorological Organization [29]. The different classes are defined  
174 according to the number of rainy days with a height between: 1 and 10 mm (P1); 10 and 30 mm (P2); 30  
175 and 50 mm (P3); >50 mm (P4).

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### 178 3. RESULTS

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#### 181 3.1. TYPOLOGY OF RAINFALL REGIMES

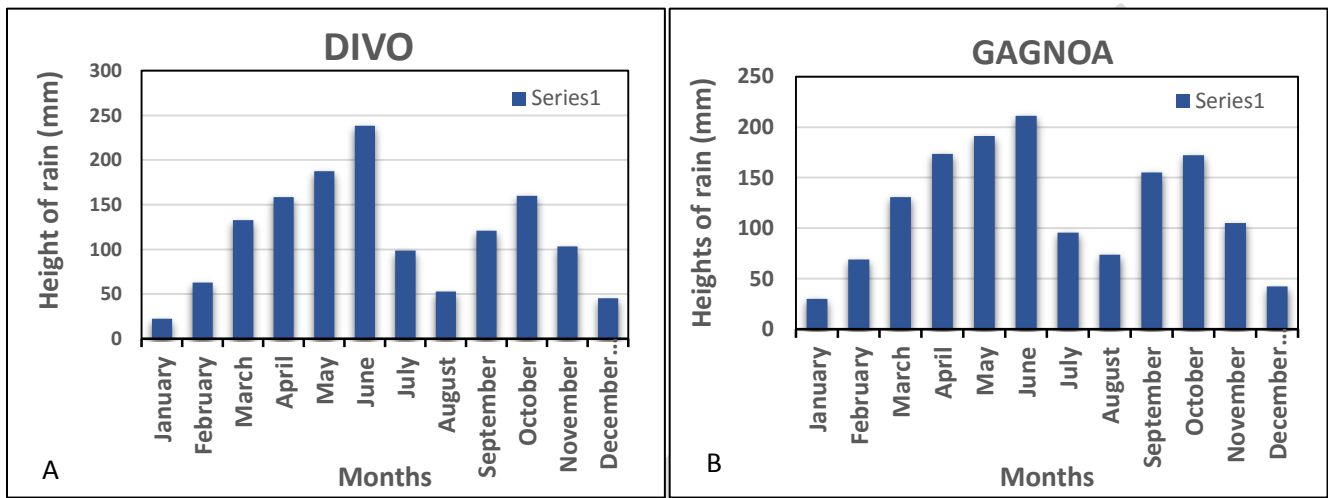
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184 The monthly average rainfall totals for Divo and Gagnoa show that the two localities studied have a  
185 bimodal rainfall pattern, characterized by two rainy and two dry seasons (Figure 2). In Divo the main rainy  
186 season starts on average in March and ends in July, while the minor rainy season begins in September and  
187 ends in November. June is the wettest month of the main season with an average maximum value of 238  
188 mm of rain and September is the wettest month of the main season with average totals of 160 mm. A small  
189 dry season (July to August) occurs between the two rainy seasons and a large dry season occurs from  
190 November to February (Figure 2A).

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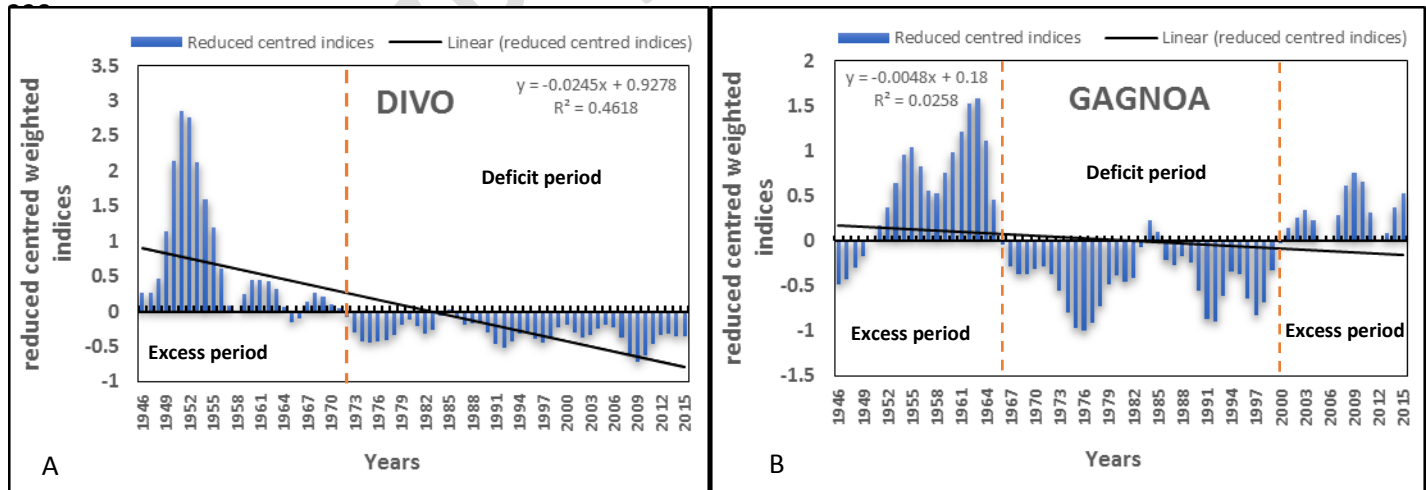
193 In Gagnoa, the main rainy season begins on average in March and ends in July. It is followed by a short  
 194 dry season from July to August. The small rainy season extends from September to November and leads  
 195 to a long dry season from December to February. June and October are the wettest months of the large  
 196 and small rainy seasons respectively with a maximum average value of 211 mm in June and 172 mm in  
 197 October (Figure 2B). In general, rains are more abundant in Gagnoa than in Divo. Indeed, we observe that  
 198 with the exception of the months of March, June and July, all the other average monthly totals recorded  
 199 during the year at Gagnoa station are higher than those at Divo station (Figure 2). It is also noted that the  
 200 months of March, April, May, June, September and October are the wettest months of the year in both  
 201 regions (Figure 2)



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219 **Figure 2: Rainfall regime at Divo and Gagnoa stations**

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221 **3.2. INTER-ANNUAL VARIABILITY AND PRECIPITATION TREND**

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224 Precipitation evolves according to two main trends in both localities. The first period, 1946-1971 in Divo and  
 225 1946-1965 in Gagnoa, reflects an upward trend in precipitation (excess period) (Figure 3). The second  
 226 period, from 1972 to 2015 in Divo and from 1966 to 2000 in Gagnoa, shows a downward trend in rainfall  
 227 (excess period). The Gagnoa station has a second (excess) wet period from 2000 to 2015 (Figure 3).



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245 **Figure 3: Interannual evolution of rainfall in Divo and Gagnoa over the period 1946-2015**

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249 **3.3. DETECTION OF YEARS OF RAINFALL BREAK**

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 251 The tests used identified ruptures in 1972 at Divo station and in 1966 at Gagnoa station (Table 1). The  
 252 methods of Pettitt, Lee and Heghinian, Buishand and Hubert have the same conclusion for the Gagnoa  
 253 rainfall series. On the other hand, the test results are more random for Divo's time series, which is much  
 254 more heterogeneous. However, these rupture dates are obtained by the majority of the tests (2/4 for Divo  
 255 and 3/4 for Gagnoa). In addition, they confirm the years of apparent breaks highlighted by the evolutionary  
 256 trends of the interannual rainfall indices at each station (Table 1).  
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258 **Table 1: Breaks in the rainfall series established by the various tests**

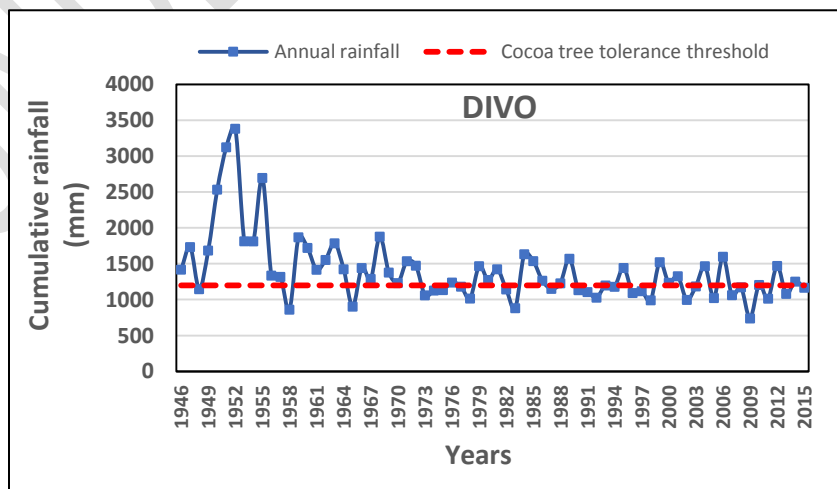
Stations	Failure tests								Date indicated by the majority of tests
	Pettitt		Lee and Heghinian		Buishand		Hubert		
	Year	Proba.	Year	Proba.	Year	Proba.	Year	Proba.	
Divo	1972	0,001	1955	0,65	1972	0,99	1953 ; 1956	0,1	1972
Gagnoa	1966	0,00678	1966	0,1968	1966	0,99	1954 ; 1965	0,1	1966

259 **Proba:** Probability

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 262 **3.4. ANALYSIS OF INTERANNUAL RAINFALL TOTALS**

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 264 **3.4.1. Interannual rainfall totals for Divo**

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 266 The evolution of interannual rainfall totals in Divo before the break-up (1946-1971 period) shows that for 23  
 267 years out of 26, the annual totals reach or exceed the minimum annual threshold required for cocoa trees  
 268 in Côte d'Ivoire, which is 1200 mm (Table 2). Eighty-eight percent of the overall water needs of cocoa trees  
 269 are therefore met. In 12% of cases, accumulations of less than 1200 mm are not sufficient to meet the  
 270 water needs of cocoa plants (Table 2). Over the period 1946-1971, the average cumulative rainfall was  
 271 1701 mm. During this period, the annual rainfall in Divo is therefore largely favourable to cocoa farming.  
 272 Over the post-breakup period (1972-2015), however, only 43% of the years meet the cocoa tree's water  
 273 requirements, and in 57% of cases rainfall is insufficient. On average, 1218 mm of rain falls in this locality  
 274 (Figure 4).  
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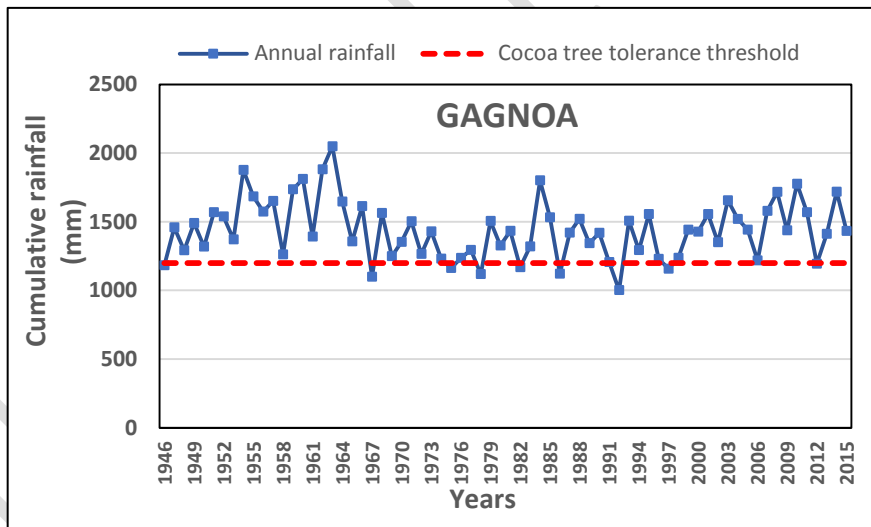
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 290 **Figure 4: Variability of interannual rainfall totals at Divo over the period 1946-2015**

291 **Table 2: Descriptive statistics of interannual rainfall totals in Divo**

Station	Divo	
Periods of time	1946-1971	1972-2015
Years of observations	26	44
Maximum	3384	1634
Minimum	861	738
Average	1701	1218
Standard deviation	614	203
Coefficient of variation (%)	36	17
Cumulative $\geq 1200$ (%)	88	43
Cumulative $< 1200$ (%)	12	57

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294 **3.4.2. Interannual rainfall totals for Gagnoa**  
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296 Gagnoa's interannual rainfall totals show a much more pronounced variability than those of Divo (Figure 5).  
297 Over the period before the break-up (1946-1965), the city of Gagnoa received an average of 1520 mm of  
298 rain. 96% of years have rainfall greater than or equal to the threshold required for cocoa production, while  
299 only 4% of years receive less than 1200 mm of rain. In contrast, in the post-rupture period (1966-2015), it  
300 rains on average 1395 mm. In addition, only 84% of years reach or are over  
301 1200 mm when 12% of years are in deficit (Table 3).  
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326 **Figure 5: Variability of interannual rainfall totals in Gagnoa over the period 1946-2015**



327 **Table 3: Descriptive statistics of interannual rainfall totals in Gagnoa**

Station	Gagnoa	
Periods of time	1946-1965	1966-2015
Years of observations	25	45
Maximum	2048	1801
Minimum	1099	1002
Average	1520	1395
Standard deviation	239	187
Coefficient of variation (%)	16	13
Cumulative $\geq 1200$ (%)	96	84
Cumulative $< 1200$ (%)	4	16

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### 3.5. MAXIMUM INTERANNUAL DRY SEQUENCES

#### 3.5.1. Maximum interannual dry sequences at Divo

334 The cocoa tree cannot tolerate the occurrence of a dry season of more than 3 months in the year. This  
335 approach makes it possible to verify that this variable dangerous for plant development and growth is not  
336 exacerbated by local climate change. Examination of the maximum interannual dry sequences A Divo  
337 shows that generally over the two periods no year has a dry sequence greater than 90 days. The average  
338 maximum dry sequence before rupture is 11 days while the maximum dry sequence after rupture is 15  
339 days. This represents an average extension of 4 days (Table 4).

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#### 3.5.2. Maximum interannual dry sequences in Gagnoa

343 In Gagnoa, there is only one year that has a dry sequence that is more than 3 months long after the rupture  
344 (93 days). The average of the maximum dry sequences increased by one day compared to the period  
345 before 1966. It has gone from 11 to 12 days. However, despite this slight extension of the maximum dry  
346 sequences, they remain less important than in Divo (Table 4).

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**Table 4: Descriptive statistics of maximum interannual dry sequences in Divo and Gagnoa**

Station	DIVO		GAGNOA	
	1946-1971	1972-2015	1946-1965	1966-2015
Maximum	57	89	61	93
Minimum	2	2	1	2
Average	11	15	11	12
Standard deviation	9	13	9	12
Coefficient of variation (%)	79	83	88	99
DS $\leq 90$ days (%)	100	100	100	99

350 **DS: dry sequences**

#### 4. DISCUSSION

It is now certain that global warming is having an impact on all regions of the world. But these demonstrations and targets are diverse. In Côte d'Ivoire, this phenomenon is mainly reflected in a disruption of rainfall patterns and an unprecedented reduction in interannual rainfall amounts, observed in most regions of the country around 1970. The study of rainfall patterns in the two localities informs us that their typology has not yet been affected by the overall decline in rainfall that occurred in the late 1960s and early 1970s in Côte d'Ivoire. The rainfall patterns in Divo and Gagnoa remained bimodal as [15]'s work on the general climate in Côte d'Ivoire had already demonstrated. Indeed, [15] had shown that the regions of Gôh and Lôh-Djiboua belong to the humid tropical zone in which the distribution of rains obeys a seasonality typical of the bimodal regime which is characterized by four seasons including two rainy seasons and two dry seasons: a major rainy season from March to June and a minor dry season in July and August, a minor rainy season from mid-September to mid-November and a major dry season from December to February. The seasonal distribution highlighted in this study in the localities of Divo and Gagnoa is generally in line with that of Eldin, with the exception of the apparent end of the high season, which occurs more and more during July, and the dry season, which is likely to be shortened in Gagnoa. This situation could be explained by the fact that Eldin's study period was fairly homogeneous (excess rainfall and less fluctuating) while the period 1946-2015 straddles two periods with opposite climatic behaviours. The analysis of Divo's average monthly rainfall totals also indicated that June and September, with average totals of 238 mm and 160 mm respectively, are the wettest months of the large and small rainy seasons. A study of the water balance in central Côte d'Ivoire, particularly in the departments of Bocanda, M'bahiakro and Dimbokro, which also have a bimodal system,[9] led to the same conclusions. Previous work by Diomandé [30] and [31] in the same region had also indicated that June is the wettest month of the major rainy season and September the best watered month of the minor rainy season. Our results showed that June (211 mm) is like Divo, the wettest month of the main season in Gagnoa but that the best watered month of the main season in Gagnoa is October (172 mm). Recent work by [14] in the same area confirms these monthly rainfall characteristics in Gagnoa. Like us, these authors have proven that the months of March, April, May, June, September and October receive the highest amounts of rainfall in the year in Gagnoa and Divo.

Moreover, the analysis of the interannual rainfall totals for the two regions investigated reveals that, thanks to post-rupture rainfall averages of 1218 mm in Divo and 1395 mm in Gagnoa, which exceed the minimum annual threshold of 1200 mm required by the cocoa tree, these two localities are still suitable for cocoa production. This result is consistent with that obtained by [32] who, in a study called rainfall variability and perspective for cocoa replanting in west-central Côte d'Ivoire over the period 1978-2007, noted that the interannual rainfall average recorded over this period (1249 mm in Divo and 1395 mm in Gagnoa) was above 1200 mm, making these two departments still favourable for cocoa production[32]. But this flattering general observation only masks the water deficit to which cocoa trees are increasingly exposed in the study area. This is the case in particular over the period 1971-2015 in Divo where only 43% of the years have accumulations above 1200 mm, the remaining 57% are in deficit for cocoa plants. This situation is similar to the one described by [14] in Divo over the period 1986-2015. These researchers found rainfall deficits in 60 to 80% of the years studied. The period 1971-2015, which includes the 1986-2015 sub-period, is therefore subject to water stress that is worrying for the future of cocoa production in the Divo Region. In the rest of their study [14] showed that the interannual rainfall totals observed in these localities reveal a deficiency in cocoa production in 50 to 80% of the years in Divo and in 20 to 30% in Gagnoa. Our study also fits into this framework by presenting more favourable rainfall conditions in Gagnoa, where it is noted that after the break only 12% of the years are below the minimum allowed.

In addition, the various statistical tests, in particular those of Pettitt, Lee and Heghinian and Buishand, detected major rainfall accidents in the rainfall series of the two localities studied. These climate anomalies, which correspond to sudden changes in stationarity in the evolution of daily time series, have been widely studied in several studies on climate variability in West Africa. As a reminder, many studies have identified changes in stationarity observed in African hydroclimatic series during the 20th century, especially those corresponding to a sudden decrease in precipitation in the late 1960s in the Sudano-Sahelian zone ([33], [34], [35], [36], [37], [38]) and in the Guinean and Sudano-Guinean zone ([39], [40], [41], [42]). This is why,[43] stated that "the sudden inflection point was observed in 1970 making it the pivotal year between two periods of distinct rainfall patterns". In our case, these rupture dates were detected by the majority of tests in 1972 in Divo and in 1966 in Gagnoa. These dates are perfectly consistent with the break-up years

407 indicated by [40] and [44] for the same locations. These ruptures are generally part of the period  
408 designated for the majority of West African countries by [2] and [15]. Indeed, by studying the evolution of  
409 the time series of 33 rainfall stations in West Africa in the Sahel, Sudano-Guinean and Guinean zones, [35]  
410 have revealed significant breaks, most of them located between 1968 and 1972 [46]. This is the same  
411 observation in our study because although the majority of authors agree that the rupture occurred in Côte  
412 d'Ivoire around 1970, this year is only given as an indication [41]. Indeed, it has been designated as a  
413 pivotal year in the evolution of time series in West Africa because it corresponds to the break-up date of  
414 most stations in the West African region. However, there are several stations that experience a break at  
415 dates other than 1970, but which are close to it. The interannual variability of precipitation in the Gôh and  
416 Lôh-Djiboua regions shows different evolutionary trends on either side of the break-up years. Thus, there  
417 are upward trends marking periods of excess rainfall between 1946 and 1971 in Divo and between 1946  
418 and 1965 in Gagnoa. However, after the break-up years, rainfall trends declined significantly. These post-  
419 and pre-break climatic provisions are corroborated by the work of [47] and by many experts such as [48]  
420 who, in a study on the impact of climate variability on coffee and cocoa production in central-eastern Côte  
421 d'Ivoire, which was the first cocoa loop, showed that the rainfall series of the Daoukro departments,  
422 Bocanda, Agnibilékro, M'bahiakro and Abengourou all break down into two periods of wet and dry or deficit  
423 and excess respectively before and after the ruptures. However, the station of Gagnoa has another surplus  
424 period after 1966, which extends from 2000 to 2015. This is due to a return to better rainfall conditions in  
425 many parts of the country, sometimes causing flooding as evidenced by the work of [41] and [10].  
426 As for the maximum interannual dry sequences, they are almost all less than 3 months [49] and even if it is  
427 true that they increase after rainfall accidents as is the case in various studies ([50], [51], [13], [52]), they  
428 remain marginal and do not significantly impact cocoa production in the regions studied.

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## 431 **5. CONCLUSION**

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433 This study, undertaken in the regions of Gôh and Lôh-Djiboua in west-central Côte d'Ivoire, made it  
434 possible to characterize the recent rainfall pattern in the study area and determine the current evolutionary  
435 trend in rainfall in the localities of Divo and Gagnoa. In general, it is noted that despite local climate  
436 changes, the bimodal rainfall regime, typical of the humid tropical climate, has remained unchanged in both  
437 Divo and Gagnoa. On the other hand, sudden changes in the average evolution of rainfall patterns  
438 occurred around 1970 (1972 in Divo and 1966 in Gagnoa). From these break-up dates, there is a general  
439 rainfall recession in the two departments studied, which manifests itself in a reduction in interannual rainfall  
440 totals and an elongation of the maximum dry sequences after the breaks. However, this downward trend is  
441 less marked in Gagnoa where the rate of satisfaction of the cocoa tree's water needs is higher. The Gôh  
442 region therefore remains more favourable to cocoa production than the Lôh-Djiboua region in this context  
443 of global warming.

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448 **COMPETING INTERESTS**

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450 "The authors stated that there are no competing interests."

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452 **CONSENT (IF APPLICABLE)**

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454 Not concerned

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456 **ETHICAL APPROVAL (IF APPLICABLE)**

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458 Not concerned

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460 **REFERENCES AND REFERENCES**

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