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Use of CHIRPS Data to Characterize Rainfall in West Africa: Case of the Poro Region in Côte d'Ivoire

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Abstract: The climatic variability observed during the last decades in West Africa results in a decrease of the rainfall that influenced resources more thus in water and lively cultural the food insecurity, the desertification, the farming exodus. Him in default not less for the Coast of Ivory. So, data of stations rainfall knew a flight, but he/it is that they are limited because of their slant and their spatial cover that don't cover the whole country. A new data set combining data of satellite and stations of observation permits a better precision in the climatic variability survey. The methods of Nicholson and filter low pass of Hanning of order 2 permitted to identify the showing a deficit and excess years. In the region of Poro two climatic periods have been identified, a period of drought of 1981 to 1993 and a humid period of 1994 to 2014. For more of precision, on a daily scale, the method of number of dry consecutive days (Consecutive Dry Days) permitted to determine the episodes of drought. The decade 1981-1990 knew a strong drought with more of 70 dry days. On the other hand, the last decade 2001-2010 marks a resumption of rains. What entails a decrease of the number of dry days in the region of Poro.

Keywords: Climatic Variability, Rainfall, Drought, CHIRPS, Spatial Analyst

1. Introduction

The climatic variations observed in the world during the last decades have influenced the agricultural resources of the African continent and they generally result in drought. This drought is expanding towards wetlands bordering the Gulf of Guinea [1]. In West Africa in particular, the notion of climate change can largely be summed up in a drastic drop in rainfall, the main climatic factor identified by [7, 3, 16]. This drop in rainfall has several consequences, including food insecurity, desertification, and rural exodus. In Côte d'Ivoire, these climatic variabilities are marked by a drop in rainfall of 20 to 40% compared to the interannual average [6, 10]. These climate variability studies also indicate the onset of frequent droughts in 1979, 1980, 1989 and from 1990 to 1999 [10], particularly in the Korhogo area in the north of the country. Satellite observation gives us good spatial and temporal coverage. Remote sensing using its synoptic vision offers us new products (time series) emanate from more reliable satellites with high precision allowing more precise results to be obtained in the study of climate variability. The objective is to study the spatiotemporal distribution of dry episodes. It will be a question of first identifying the years and months in deficit. Then, determine the episodes of extreme droughts and see their evolution over the last three (3) decades (1981-1990, 1991-2000, 2001-2014). Finally, make a spatial distribution of these episodes.

2. Presentation of the Study Area

The Poro region is in the North of the Ivory Coast between 5° 3 and 6° 46 West longitude, then 8° 32 and 10° 42 North latitude. The region covers an area of 13,400 km^2 for a population of 763,852 inhabitants [8], i.e., a population density of 57 inhabitants / km². This population is mainly made up of farmers. This region has a humid tropical climate with an average annual rainfall fluctuating around 1200 mm for the last 3 decades. The Poro region has two seasons, a dry season, and a rainy season which lasts 7 months and runs from April to October, with a maximum of 255-267mm of rain in August and September. This region has average daily temperatures of 29°C in the dry season and 25°C in the rainy season [9].

3. Material and Methods

Study data Climate Group Hazards IR Precipitation (CHIRPS) is a precipitation data set from products combining data from satellite and ground stations. These data cover almost the entire globe. In Africa, the spatial coverage ranges from 40N-40S, 20W-55E with a resolution of 5.3km. They are available for more than 30 years (1981 to present) with monthly, decadal, pentadal and daily rainfall [5]. In this study, the annual, monthly, and daily products from 1981 to 2014 for studies of climate variability were used.

3.1. Methods of Studying Climate

Variability Interannual precipitation variables

The interannual variability of precipitation was determined by two methods: the Nicholson rainfall index and the Hanning low pass filter of order 2.

3.2. Nicholson Rainfall Index or Center-Reduced Variable

For the analysis of the hydroclimatic parameters, we proceeded to the calculation of the Nicholson index. It allows to observe the interannual variability of precipitation. This index identifies the surplus and deficit years according to equation (1):

$$I_i = \left(\frac{X_i - \bar{X}}{\sigma}\right) \quad (1)$$

Avec: I_i: *Indice pluviométrique;* X_i: *Hauteur de pluie de l'année i (en mm);* $\bar{X}$: *Hauteur de pluie moyenne sur la période d'étude (en mm); σ: Écart type de la hauteur de pluie sur la période d'étude.*

3.3. 2nd Order Hanning Low-pass Filter

This method was used to better appreciate interannual rainfall fluctuations. It consists of eliminating seasonal variations by weighting the annual rainfall totals from the equations of Assani [2].

$$X_{(t)} = 0{,}6X_{(1)} + 0{,}25X_{(t-1)} + 0{,}38X_{(t)} + 0{,}25X_{(t+1)} + 0{,}6, X_{(t+2)}; \quad (2)$$

for 3 ≤ t ≤ (n - 2)

Where $X_{(t)}$ is the weighted rainfall total of term t, $X_{(t-2)}$, $X_{(t-1)}$, represent the observed rainfall totals of the first two terms preceding the term $X_{(t)}$ and $X_{(t+1)}$, $X_{(t+2)}$ are the observed rainfall totals of the first two terms following the X_t, term. The weighted rainfall totals of the first two (X_1, X_2,) and last two ($X_{(n-1)}$, $X_{(n)}$) terms of the series are calculated using the following equations (n: size of the series).

$$X_1 = 0{,}54X_1 + 0{,}46X_2(\mathrm{t}-1) + 0{,}38X_{(t)} + 0{,}25X_{(t+1)} + 0{,}6X_{(t+2)} \quad (3)$$

$$X_1 = 0{,}54X_1 + 0{,}46X_2 \ (3); X_2 = 0{,}25X_1 + 0{,}50X_2 + 0{,}25X_3 \quad (4)$$

$$X_{(n-1)} = 0{,}25X_{(n-2)} + 0{,}50X_{(n-1)} + 0{,}25X_n \quad (5)$$

$$X_n = 0{,}54X_n + 0{,}46X_{(n-1)} \quad (6)$$

The centered and reduced indices of the weighted annual rainfall heights obtained are then determined according to Equation (1). These methods made it possible to see the years in deficit. For more details we have determined the deficit months of the different years. For the study of these months, we used the monthly data and then calculated their trends to see their evolution by decade.

3.4. Calculation of the Climate Index

For more precision, we also used the daily data. These data allowed us to determine extremely dry episodes using the Consecutive Dry Days (CDD) index. This index gives the maximum number of consecutive days for which the precipitation is less than 1 mm (RR <1mm).

4. Results

4.1. Interannual Precipitation Variables

The interannual variations in rainfall represented in centered-reduced values in Figure 1 show a succession of positive values and negative values. These values define the alternation of wet and dry years. The regression line of equation y = ax + b shows an increasing trend with a relatively weak slope (a = 0,028) hence a small interannual variation.

Figure 2 gives more precision on the interannual variability. It has two major climatic periods. A dry period which extends from 1981 to 1993 and a wet period ranging from 1994 to 2014. The dry period is pronounced in the years 1981, 1982, 1983 and 1984 with rainfall indices going to about -3. It is also encrusted with a few wet years (1988 and 1989). As for the wet period, it extends over many years and during this period there are two dry years 2005 and 2006.

We see a variability of the deficit months over the different years. The observation made over the first decade (Figure 3a) shows that the dry months extend over an average of 6 months and the maximum was recorded in 1988 with 8 dry months. Unlike the first decade, Figure 3b

(1991-2000) shows almost homogeneity in the number of dry months with an average of 5 months. This decade recorded a maximum of 6 dry months in 2000 and a minimum of 4 months in 1993. We note an alternation between 5 and 6 dry months after every two years in the decade 2001-2010 (figure 3c). Overall, this decade appears to be normal with an average of five (5) dry months.

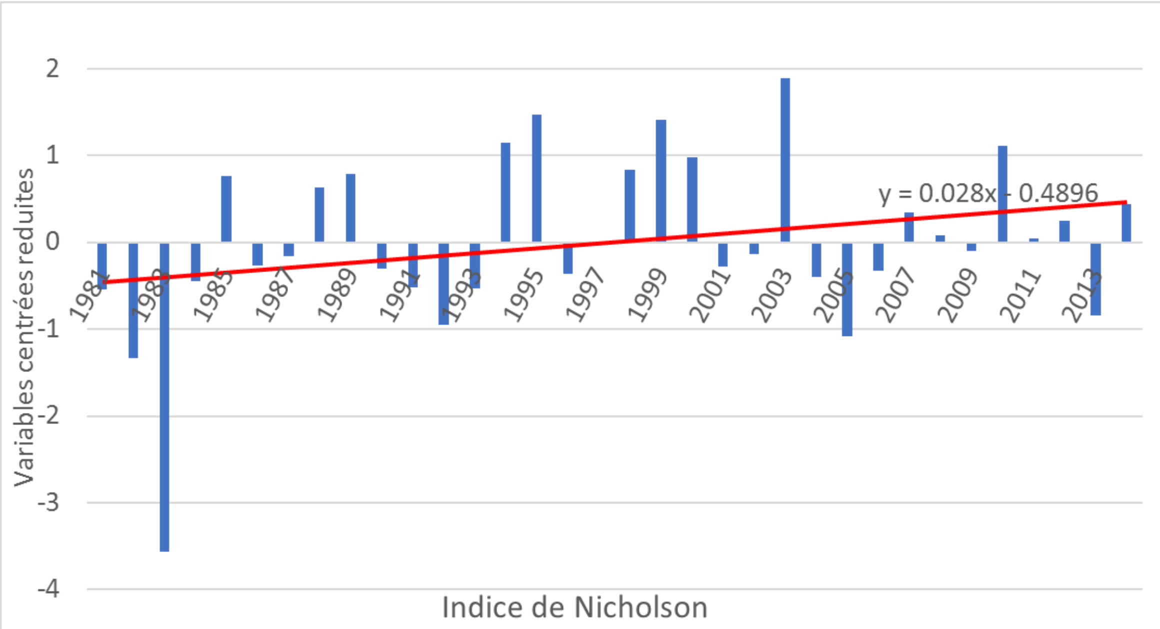

Figure 1. *Annual rainfall reduced centered.*

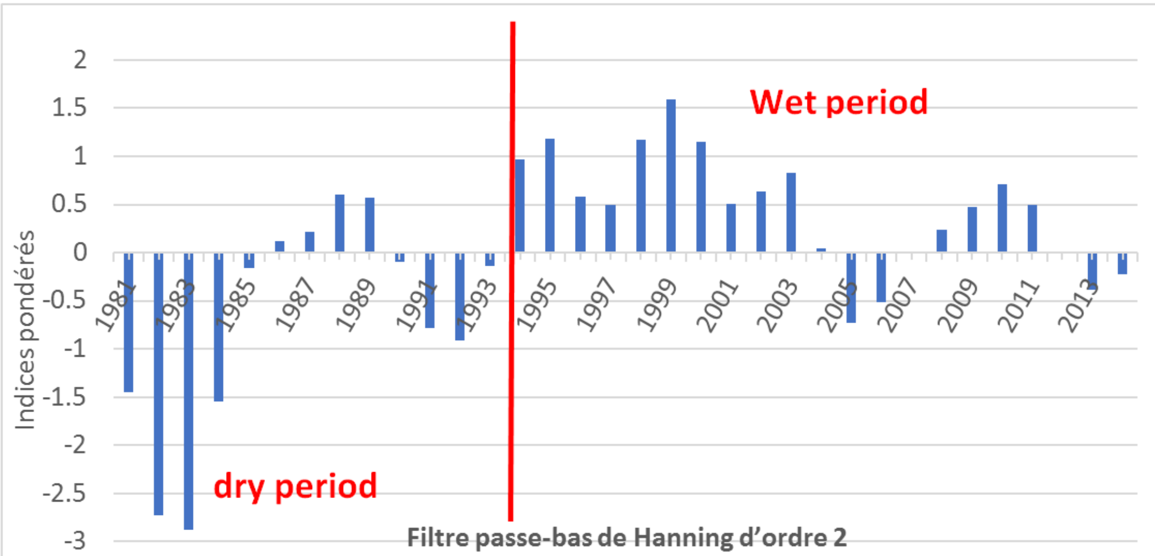

Figure 2. *Weighted indexes reduced centered rainfall.*

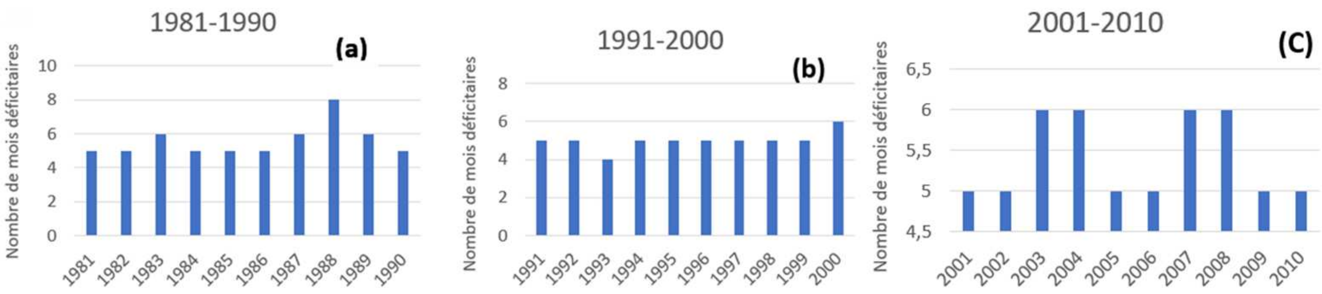

Figure 3. *Number of months in deficit per year.*

4.2. Year-to-Year Variation of the CDD (Consecutive Dry Days) Index

The calculation of the CDD index shows a large variation in extremely dry events. The finding in Figure 4a shows a decrease in the trend in the number of dry days. In addition, the year 1988 was marked by a severe drought with 60 dry days. The decade 1991-2000 (Figure 4b), however, saw an increase in extremely dry episodes ranging from about 43 to 48 dry days. The maximum of this decade was recorded in 2000 with about 60 dry days. Unlike the previous decade, that of 2001-2010 (Figure 4c) shows a decrease in the dry day trend. The highest number of dry days observed during this decade is 60 in 2006. Overall, the number of extremely dry episodes is declining throughout the time series (Figure 4d).

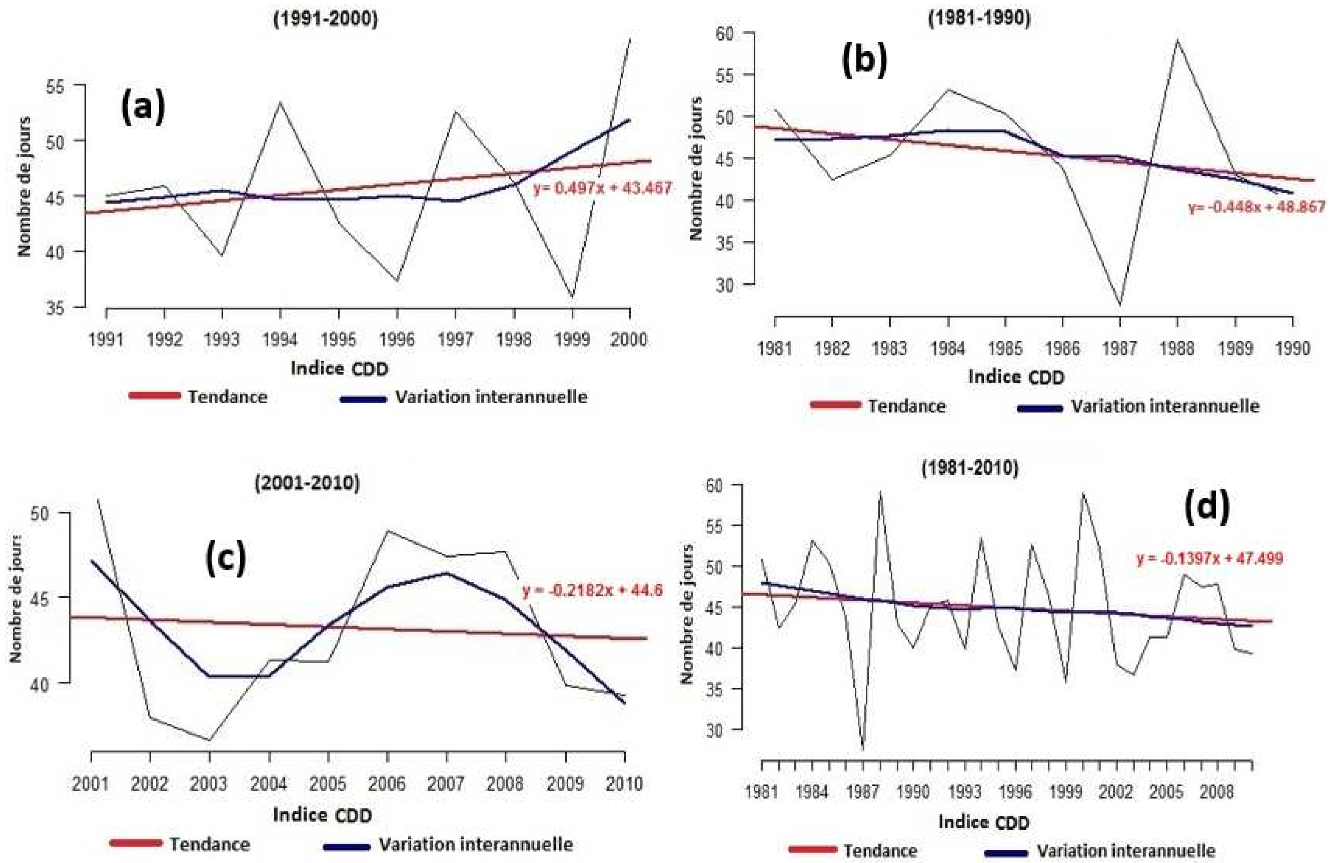

Figure 4. *Trend of extremely dry episodes by decade.*

4.3. Spatial Distribution of Dry Episodes

Figure 5 below presents the different trends of the dry season (November-March) by decade or the millimeter of rain gained or lost per decade on average. The Poro region had rainfall losses during the decade 1981-1990 (Figure 6a). It recorded rainfall losses ranging from 10 to 50 mm over its entire area. In the following decade (1991-2000), rainfall losses persisted even more in the southern zone of the region with values still ranging from 10 to 50mm (Figure 6b). On the other hand, the North zone observed a decrease of between -10 and 10mm. As opposed to the first two decades, that of 2001-2010 recorded an increase in rainfall from 11 to 30mm in the north of the region and this gradually increased going south to reach a maximum of 100mm (Figure 5c). Throughout the chronicle (1981-2014), we observe a trend throughout the region that varies over more or less 10mm of rain (Figure 5d).

Figure 6 below illustrates the spatio-temporal distribution of extremely dry episodes in the Poro region. During the decade 1981-1990 we observe a variation of extremely dry episodes from 30 to 70 dry days. The severe drought was observed in the center-east in the localities of Korhogo and Sinematiali, and in the north in the locality of M'Bengué and around with more than 60 dry days. The localities of Napiélédougou and Dikodougou record few extreme episodes unlike the other localities (Figure 6a). The second decade 1991-2000 (Figure 6b) notes a maximum in Korhogo and its surroundings (in the center) with about 70 dry days. The area between latitudes 9° 2 N and 8° 5 N is homogeneous with 40 to 50 dry days. Above these latitudes the area is contrasted, and this is also the case for the decade 2001-2010. During this decade, we identify an area with heterogeneous spatial distribution with values that vary from 30 to 70 dry days (Figure 6c).

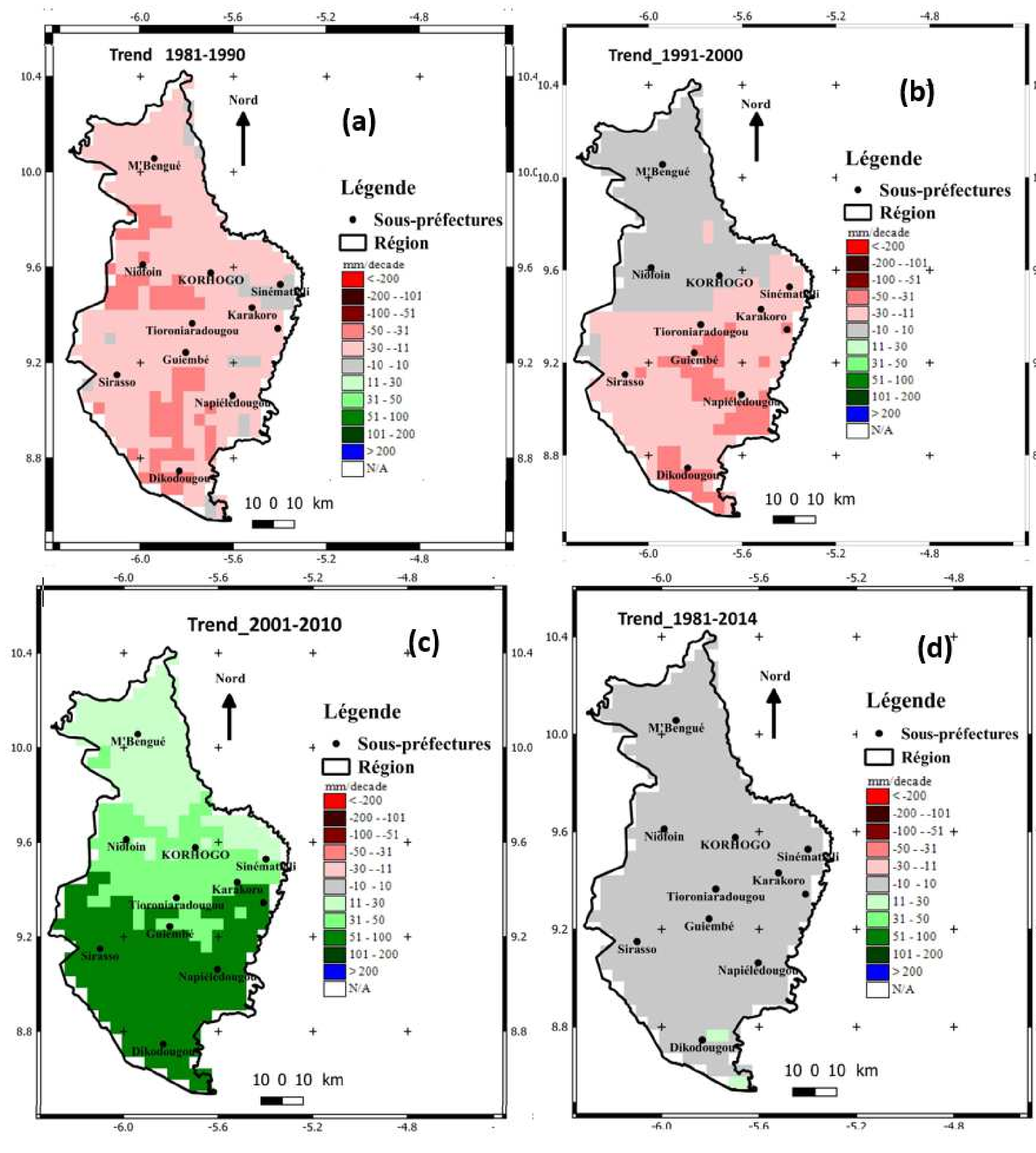

Figure 5. Rainfall trend from November to March by decade. Red colors indicate the millimeter lost per decade and colors from green to blue indicate a gain of mm per decade on average with few episodes.

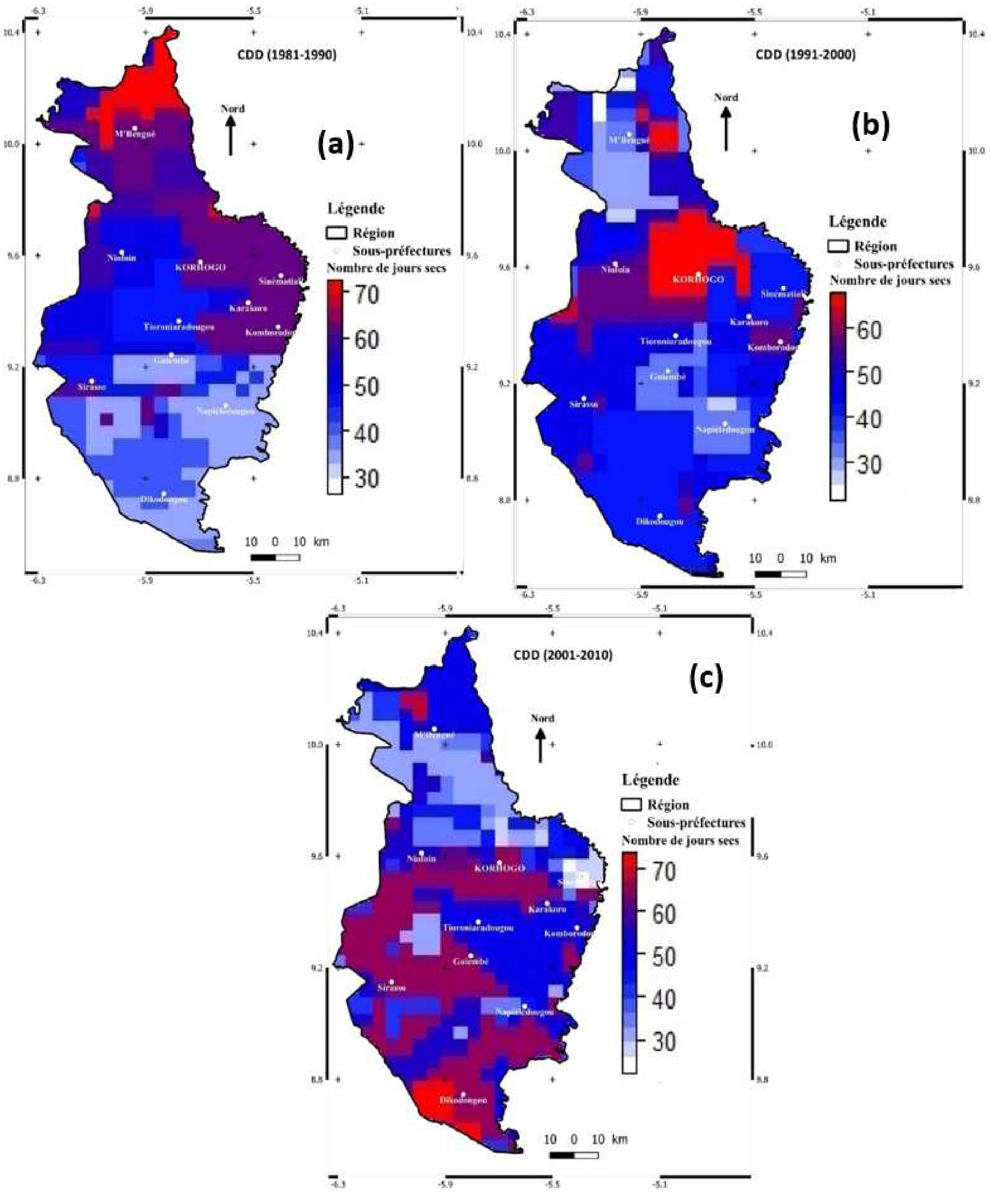

Figure 6. *Spatial distribution of extreme dry episodes in the Korhogo region.*

5. Analysis and Interpretation of the Results

5.1. Interannual Variability of Rainfall

The temporal analysis of annual precipitation with CHIRPS data has revealed two climatic periods (dry and wet) during the last three decades. This decline was pronounced from 1981 to 1984 and this is part of the interval of the great drought experienced by West Africa in the 70s, 80s, 84, 90 and 2006 [13, 15] and [14]. The abundant and exceptional rains recorded during the decade 1994-2003 contributed to modifying the trend towards humidity. This trend announces a return of precipitation. The spatio-temporal variability study of annual rainfall carried out by [11] confirms this recovery. But this period of humidity experienced a decrease during the decade 2004-2014 with rainfall deficits recorded in 2005-2006 and 2013-2014. The seasonal variation observed over the decades gives more details on the interannual variation. During these three decades, there was a variation of 4 to 8 dry months and on average 5 dry months were recorded. Which agrees with the statements of [9]. According to him, the Korhogo region has a single rainy season which lasts 7 months and runs from April to October. Therefore, the dry season lasts 5 months (November to March). For more precision in the drought study, we determined the extreme dry episodes. The observation made over the various present decades of the evolution of extreme dry episodes in the region. The decade 1981-1990 recorded two peaks in 1984 and 1988. This agrees with the severe drought identified in 1983/84 (figure 3). In the second decade 1991-2000, we note an increase in the trend of dry days. This is explained by the fact that we are in the dry period [9]. However, the observation made over the decade 2001-2010 shows a decrease in the trend of extreme episodes. But there was a peak of 50 dry days in 2006. This decrease can be explained by the resumption of rain observed in West Africa at the beginning of the 21st century. This is discussed by [12]. Throughout the long rainfall chronicle (1981-2014) a decrease in the trend of extreme dry episodes was observed. This can be explained by the resumption of rains but also by the geographical location of Côte d'Ivoire which is in the subequatorial region bordering the Gulf of Guinea.

5.2. Spatio-temporal Variability of Dry Episodes

The analysis of the spatio-temporal variability of the dry months shows that the Poro region recorded a loss of rainfall of 11 to 50mm over its entire surface in the first decade (1981-1990) and in the second a reduction in losses (over 30mm) was noted in the northern area of the region. This is in line with the results of the annual variation in rainfall obtained in Jourda's thesis (2005) which identifies two dry periods 1969 to 1978 and from 1983 to 1998. On the other hand, the third decade sees an increase in rainfall throughout the region (the North recorded a gain of 11 to 50mm and the South a gain of 51 to 100mm). We notice a gradual increase in rainfall during these decades. This result reflects the resumption of rain observed in West Africa. This agrees with the result of the interannual variability in figure 2. We observe a decrease in rainfall losses over the entire area of interest throughout the chronicle. To be more precise, a study of extreme episodes was carried out and the results obtained make it possible to identify these episodes by decade (figure 6). The first decade shows severe drought in the Center-East and the North in the M'Bengué sub-prefecture. This can be explained by the proximity of these areas to the Sahelian region which experienced a period of drought from 1968 to 1995 [4]. The last two decades marked the beginning of the resumption of rains with regression of drought, but we note the relocation of the extreme in the Korhogo department in the decade 1991-2000.

6. Conclusion

At the end of this study, it emerges that CHIRPS data can be used for the characterization of climate variability. The use of the CDD method made it possible to determine the episodes of severe drought. A severe drought was identified in the Center-East zone and in the North of the Poro region in the M'Bengué sub-prefecture with more than 70 dry days in the decade 1981-1990. The second decade (1991-2000) saw a decrease in drought throughout the region, and a maximum of over 60 dry days was observed in the department of Korhogo. But in general, the observation is that the trend of extreme drought is downward throughout the chronicle (1981-2014). We also note that the extremes are not too noticeable in Côte d'Ivoire due to its geographical position.

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