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INVESTIGATION ONTHE 1970S AND 1980S DROUGHTS IN FOUR TIRBUTARIES OF THE NIGER RIVER BASIN (WEST AFRICA)

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ABSTRACT

West Africa has experienced severe droughts during 1970s and 1980s. On the other hand, the region is characterized by high inter-annual rainfall variability and there seems to be a recent recovery. But has the drought stopped? To answer this question, we evaluated spatio-temporal pattern of rainfall and runoff in four tributaries (Sota, Alibori, Mekrou and Kompa-gorou) of the Niger River basin, covering a total area of 40,000km^2 for the period 1971 to 2010. First, decadal rainfall variability was investigated using Kriging-based isohyets. Cross entropy method was then applied to detect breakpoints in rainfall and runoff series. Additionally, the rainfall-runoff relationship was assessed via Spearman's rank correlation coefficients. Yet the drought started in 1970s peaked in 1980s, but the wetness of the last two decades led to an overall increase of both rainfall and runoff over the study area. Though a moderate to strong (0.57-0.66) rainfall-runoff correlation was obtained for three of the four investigated catchments, the breakpoints in rainfall and runoff series were not per se consistent probably due to gaps in discharge data. Rainfall depicted a shift around 1992 but runoff around 1983. The wetness of the decades, 1990s and 2000s and the manifold floods records of this first half of 2010s over West Africa are evidences that the droughts of 1970s and 1980s have stopped.

Keywords: Drought, Recovery, Breakpoint analysis, Cross-entropy method, Niger River basin

1. INTRODUCTION

There is a consensus regarding the break of early 1970s in hydro-climatic series and the correlated drought and famine of 1980s in West Africa, (Goula et al., 2007; Mahé et al., 2005; Nicholson., 2001; Omotosho, 2008; L'Hote et al., 2002). However, while certain authors demonstrated that the drought is still continuing, others proved that it has stopped. Omotosho (2008) reported a shift to recovery at the station of Kano (Sahelian zone of Nigeria) in recent years with the period1996-2000 being the wettest 5-years period since 1931, whereas L'Hote et al. (2002; 2003) demonstrated that the drought of 1980s continues. Paturel et al. (1998) pointed out the succession of wet and dry decades during both halves of the twentieth century along with a heterogeneous manifestation of the drought in space within 16 non-Sahelian West and Central African countries. Lebel and Ali (2009) specified that the recovery was complete in eastern Sahel, almost complete in central Sahel but not yet actual in western Sahel. In this debate, certain zones get only little attention. It is for instance the case of upper Benin Republic which is located in the Sudanian zone of West Africa and the study area for this work. The research area (40,000 km2) is an active part of the transboundary Niger River basin. Home for more than 1.5 million people (RGPH4, 2013); it constitutes the largest cotton and vegetable production, as well as cattle breeding zones of the country. It also contains the W Park, one of the most important West African wildlife parks. Contrary to the ecosystem services this area provides, there are very few studies undertaken in that area (Vissin, 2007), and unfortunately, these studies are limited to the period 1955-1992 only. The aim of the present study is to investigate whether the great drought is still continuing in the research area.

2. MATERIALS AND METHODS

2.1Study area

The study area is made up of 4 tributaries of the Niger River basin: Mekrou with a catchment area of 10,552 km^2, Alibori 13,684 km^2, Sota 13,449 km^2 and Kompa-Gorou 2,041 km^2. 95% of the area of these basins is located in Benin Republic and situated between 1°50' and 3°75' W longitude and 10°0' and 12°30' N latitude. Characterized by a

unimodal rainfall regime, the mean annual rainfall of the area for the period 1971-2010 is about 936 mm, with mean minimum and maximum temperatures of 21.5°C and 34.6°C respectively.

2.2 Data sources

Data were collected from different sources as shown in Table1.

Table 1 : Data sources. DMN stands for Direction Météorologique Nationale, CeRPA for Centre Regional de Production Agricole, DGEau for Direction Générale de l'Eau

Data	Number of stations & period covered	Data type	Sources
Climate	27 stations 1970-2010	Rainfall	DMN Benin, CeRPa Benin, DMN Burkina Faso and Niger Met. Office
Discharge	05 stations 1970-2010	- Discharge	DGEau

2.3 Inter-decadal rainfall variability

Using annual rainfall data, decadal rainfall variability was investigated via Kriging-based isohyets.

2.4 Breakpoints analyses of rainfall and runoff

Cross entropy method (Priyadarshana & Sofronov, 2014) embedded in R software was applied to detect the breakpoints in rainfall and runoff series. By providing multiple breaks and by offering the possibility for the user to choose the number of breaks desired, the cross entropy method seems appropriate to the context of high inter-annual rainfall and runoff variability of West Africa. The determination of the breakpoint in rainfall and runoff data was done first for individual rain gauge and hydrometric station using cross entropy technique and then for the entire research area by applying the t-test at 5% level of significance.

2.5 Correlation of rainfall-runoff relationship

Mean annual catchment precipitation was computed using Thiessen polygon method. The correlation rainfall-runoff was investigated by assessing Spearman's rank coefficients (Spearman, 1904).

3. RESULTS AND DISCUSSION

3.1Inter-decadal rainfall variability

A visual inspection of Figure 1 reveals that for the decade 1970s, the isohyets varied between 1150mm and 700mm. They dropped down in between 1050mm and 650mm during the decade 1980s. However, in contrast to the two previous decades, they jumped up in between 1300mm and 750mm and in between 1250mm and 750mm respectively for the decades 1990s and 2000s. An overall increase of rainfall was hence observed for the research area.

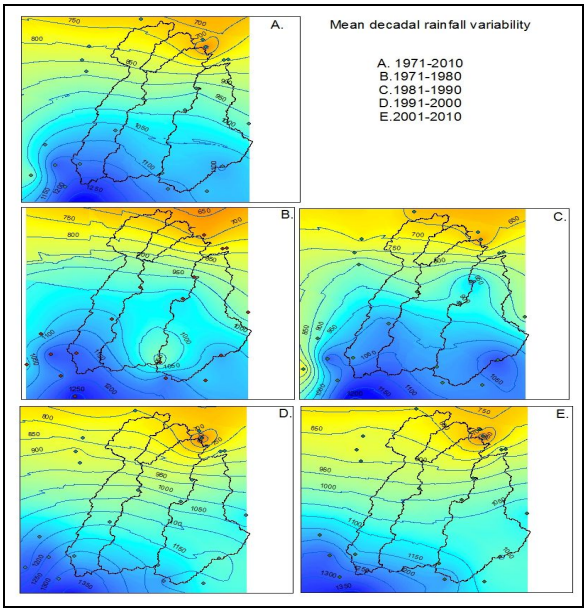

Figure1: Mean decadal rainfall variability

3.2 Breakpoints analyses of rainfall and runoff

The result of breakpoint analysis at individual rain gauge is given in Table 2 below. The application of the t-test resulted for the entire area in a break (hereafter referred as Break-1) around 1992 ±2.5 years.

Table 2: Year of break in rainfall data. Rain gauges are ordered from the South to the North of the study area

Station	Longitude	Latitude	Year of break
South			
Parakou	2.60	9.35	1988
Djougou	1.67	9.70	2003
Nikki	3.20	9.93	1988
Ina	2.73	9.97	1988
Birni	1.50	10.00	1997
Boukoumbe	1.10	10.17	1991
Bembereke	2.67	10.20	1988
Kalale	3.38	10.30	1989
Natitingou	1.38	10.32	2003
Kouande	1.68	10.33	1991
Tanguieta	1.27	10.62	1991
Centre			
Kerou	2.10	10.83	1979
Segbana	3.70	10.93	1996
Kandi	2.93	11.13	1998
Banikoara	2.43	11.30	1994
Alfakoara	3.07	11.45	1997
North			
Mahadaga	1.75	11.70	1986
Malanville	3.40	11.87	2003
Namounou	1.70	11.87	1988
Gaya	3.45	11.88	2003
Karimama	3.18	12.07	No break
Diapaga	1.78	12.07	1994
Fada	0.35	12.07	1991
Ouna	3.15	12.17	1989
Tapoa	2.40	12.47	1994
Tamou	2.17	12.75	1987
Niamey	2.17	13.48	1989

Table 3 displays, for each hydrometric station, the year of breakpoint in runoff data. For the entire area, the application of the t-test resulted in a break (hereafter referred as Break-2) in 1983 ±6.8years.
At first glance, there is a mismatch between Break-1 (1992 ±2.5 years) and Break-2 (1983 ±6.8years). Gaps in runoff data within the period 1993-2003 might be the cause of such a difference. However, the upper limit of Break-2 (1989-1990) is in line with the lower limit of Break-1 (1989-1990). Thus, one might be tempted to establish a consistency between the two breakpoints. These results and those of the section 3.1 show that the shift to wet condition in the research area as a whole occurred around 1990. Similar conclusions were drawn by Lebel and Ali (2009) and Omotosho (2008) who reported the cessation of the drought in eastern Sahel and in northern Nigeria (station of Kano) respectively.

Table 3: Year of break in runoff series.

Station	Longitude	Latitude	Year of break
Kompongou	2.195	11.399	1986
Yankin	2.661	11.247	1975
Malanville	3.396	11.88	1982
Gbasse	3.25	10.978	1988
Couberi	3.326	11.737	1988

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3.3 Correlation of rainfall-runoff relationship

As can be seen in the Table 4, the rainfall-runoff correlation was moderate to strong for all catchments with the exception of Gbasse. Data quality (49% of gap) of the station of Gbasse might be questionable and responsible for the poor rainfall-runoff relationship.

Table 4: Spearman rank coefficients of correlation rainfall-runoff and the corresponding p-values

Station	ρ	p-value
Kompongou	0.571	0.01851
Yankin	0.664	0.0001661
Couberi	0.660	7.96e-05
Gbasse	0.332	0.141

4. CONCLUSIONS

An update of recent rainfall and runoff variability in 4 non-Sahelian tributaries of the Niger River basin has been done through this study. Despite moderate to strong (0.57-0.66) rainfall-runoff correlations for three of the four investigated catchments and probably due to gaps in discharge data, the break in rainfall and runoff data were not per see consistent. Runoff depicted a jump in 1983 ±6.8 years whereas the shift in rainfall occurred in 1992 ±2.5 years. We demonstrated that the cessation of the great drought of the 1970s and 1980s occurred around 1990 in the research area.

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