International Journal of Advanced Engineering Research and Science (IJAERS)
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-8, Issue-4; Apr, 2021
Journal Home Page Available: https://ijaers.com/
Journal DOI: 10.22161/ijaers
Article DOI: https://dx.doi.org/10.22161/ijaers.84.15

Thermopluviometric Extremes in the Municipalities Djougou and Ouake

Hervé Dègla Koumassi[1], Romaric Ogouwale[2]

[1]Institute of geography, Land Development and Environment University of Abomey-Calavi, Republic of Benin (IGATE/ UAC)
[2]Department of Geography and Land Development, University of Abomey-Calavi, Republic of Benin (DGAT/UAC)
12 Pierre Pagney Laboratory: Climate, Water, Ecosystems and Development: (LACEEDE), University of Abomey Calavi,B.P 526, Cotonou Republic of Benin,

Received: 04 Jan 2021;
Received in revised form:
04 Mar 2021;
Accepted: 29 Mar 2021;
Available online: 15 Apr 2021

***Keywords*— Extremes themopluviometric, Commune, Djougou, Ouaké.**

***Abstract*— Climate change is a great challenge of the century, requiring a global response. Climate change is hastening, the poorest and most vulnerable communities are most affected. Forecasting weather and hydrological phenomena is a crucial element in implementing operational management strategies.**

To achieve this, daily temperature and rainfall records from 1951 to 2015 are extracted from the Weather-Benin database. Daily temperature and rain projections (2006-2050) are provided by Climate Analytics. SPI has been used to characterize the magnitude of hydroclimatic hazards. Seven of the twenty-seven indices of the RClimDex software were used to characterize extreme weather events.

It results that the study area is frequently subject to episodes of short droughts (SPI1 and 3). The increase in successive dry days in the municipalities of Djougou-Glazoué is explained by the fact that the slopes (slope) are above 0 and are respectively 0.059; 3,19; 0,48; 0.52 and 0.057 with a significance p-values which values are equal to 0.78; 19,6 ; 0,059; 0,016; 0,82. Similarly, the 99th percentile shows an increase in positive slope and p-value meaning levels of 0.628 and R2 of 0.4%, respectively. These various extreme events increase the vulnerability of communities, producers, households and women farmers' groups.

I. INTRODUCTION

Global warming observed for more than a century affects not only the average temperature, but the entire statistical distribution of temperatures, i.e. the full range of possible temperatures possible at a place and time (J.CATTIAUX, 2020, p.2)

According to the IPCC's Fifth Assessment Report (2017), climate change is expected to increase climate risks in many regions, mainly in low-income developing countries, over the course of the 21st century, compared to a baseline situation without climate change. The most vulnerable sectors identified by the IPCC (2007b) include agriculture, food and water. Sub-Saharan Africa is likely to suffer most not only in terms of reduced agricultural productivity and increased water insecurity (B.O. Elasha, 2009, p 4) but also from increased exposure to coastal floods, extreme weather events and increased risks to human health.

Extreme weather events weaken affected vulnerable households by destroying their livelihoods, reducing their purchasing power and weakening their resilience already reduced by structural factors such as poverty, limited access to basic services and volatile food prices (FAO, 2011, p.7). The capacity of local people and governments to cope with natural disasters remains relatively low, and extreme weather events that increase in frequency and impact in the context of global climate change are direct threats (FAO, 2011, p.7).

The identification of extreme events is needed so as to help decision-makers in all sectors of activity assess the consequences of climate change or implement adaptation measures.. Predicting extreme weather and hydrological events that could lead to floods and droughts is a crucial element in anticipating, preparing for, and implementing individual and collective measures to ensure people's safety and property at the local level. That's why this research aims to analyze the rainfall extremes triggering extreme events in the Municipalities of Djougou and Ouaké.

II. INTRODUCING THE STUDY ENVIRONMENT

The Municipalities of Djougou and Ouaké lie between 9-20' and 10-20' north latitude and between 1-20' and 2'10' of east longitude and extend over an area of 5466 km2 (Figure 1). The communal doublet is limited to the north by the Municipalities of Ouassa Péhunco and Copargo, to the south by the Municipality of Bassila, to the east by the Municipality of Tchaourou , Sinendé and N'dali and the west by the Republic of Togo.

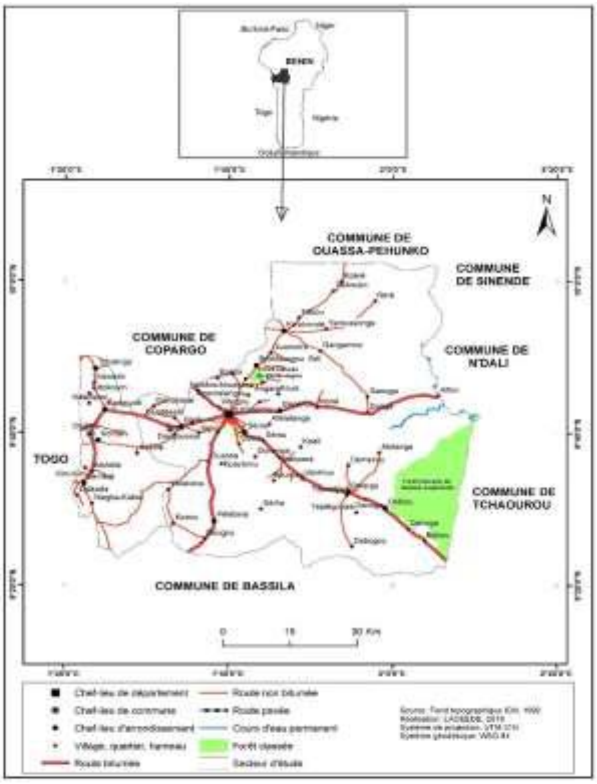

Fig 1: Geographical and administrative locations of Djougou and Ouaké

The climate in the municipalities of Ouaké and Djougou is of the Sudan-Guinean type, with an alternation of two seasons: a dry season from mid-October to mid-April followed by a rainy season covering the period from mid-April to mid-October. The precipitations, often random, range from 800 mm to 1300 mm and can reach or exceed the remarkable height of 1500 mm. The months of August and September are usually the wettest months of the year.

At pedagogical level, soils are largely ferruginous (lasterine soils, gravel, stony) low in humus and shallow on which the vegetation cover is essentially shrub or tree savannah. The most common species are: shea (V*ittelaria paradoxa*), nere (*Parkiabiglobosa*), baobab (*Adansoniadigitata*) and prowler (*Borassus aethiopium*); acacia spp, Burkeaafricana. Favourable crops on these soils are: cotton (*Gossypium sp.)*, peanut (Arachishypogaea), maize (Zeamays); mil (*Panicum miliaceum*), sorghum (*Sorghumbricolor*), yam (*Dioscorea spp*.) and cassava (*Manihot esculenta)*.

III. METHODOLOGICAL APPROACH

3.1- Data used

The climatic variables used in this study are mainly temperature records and rain heights at the daily time of 1951 to 2015 extracted from the Weather-Benin database. Future climate projections of daily temperature and rain (2006-2050) provided by Climate Analytics. These climate projections based on four regional climate models (RCM) for the RCP4.5 emission scenario were provided for the analyses. The GCM-RCM combinations considered in this study include MPIESM-REMO, HADGEM2-CCLM4, ECEARTH-RACMO and IPSL-RCA under RCP 4.5 scenario.

3.2- Method of characterizing climate extremes

3.2.1- Standardized Precipitation Index (SPI)

The SPI index was designed to quantify precipitation deficits at multiple time scales. The standardized precipitation index is a statistical indicator that assesses or characterizes the magnitude of hydro climatic hazards in a series of data (Mckee et al., cited by H. Koumassi (2014, p. 83). It quantifies the difference in precipitation over a period, deficit or surplus from historical average precipitation in a series of historical data. To characterize the magnitude and intensity of weather droughts, very simple and effective weather drought indices such as the standardized precipitation index are used (C. Faye et al.; 2017, p.3). The standardized index is based on the equiprobability of transformation of rain values, aggregated to k-month in normal standard values, with k generally set according to the objectives of the analysis (e.g., k - 1, 3, 6, 9, 12, 24, 36 months). For Nora et al (2017), the SPI index offers good flexibility of use: it can be calculated for multiple time scales and when it covers a relatively short period of time, between 1 and 3 months, for example, the SPI index can quickly detect and assess drought situations. According to McKee et al. (1993); Guttman (1998) taken over by Koumassi (2014, p.85), PPIs are based on the definition of a threshold for whether or not to declare a dry or wet year. It is obtained using the WMO's SPI SL_6 software (2012), available on http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx: The calculated SPI indices are interpreted according to the classes in Table I

Table I: Grades and interpretation grid of SPI showing damp periods.

SPI grades	Interpretation grid
2 and more	*Extremely wet*
1,5 to 1,99	*Very wet*
1 to 1,49	*Moderately wet*
-0,99 to 0,99	*Close to normal*
-1 to -1,49	*Moderately dry*
-1,5 à -1,99	*Very dry*
-2 and less	*Extremely dry*

Source: Mckee et al., (1993)

3.2.2- Method of characterizing other extreme indices

The variability of extreme weather events is highlighted in this study by calculating the indices of the RClimDex software. This software contains twenty-seven indices suggested by the team of Experts on Climate Change Index Detection (Expert Team on Climate Change Detection Indices ETCCDI). Detailed descriptions of these indicators and the RClimDexs software are available on the web of the ETCCDI (http://cccma.seos.uvic.ca/ETCCDMI/software.shtml). In this study, 7 indices were calculated including five (05) of extreme precipitation (table II). The remaining two (02) indices were devoted to minimum and maximum temperatures.

Table II: Climate Extremes Indixes

Acronyms	***Precipitation Indices***
SPI	*Standardized Precipitation Indices*
CDD	*Consecutive Dry Days*
CWD	*Consecutive Rainy Days*
SDII	*Simple Intensity of Rains*
R95p	*rainy days*
R99p	*Extremely rainy days*
	Temperature indices
TXx	*Maximum of Tmax*
TNx	*Maximum of Tmax*

Source : http://cccma.seos.uvic.ca/ETCCDMI/software.shtml

IV. RESULTS

4.1- Descriptive statistics of the evolution of climate indices

Table III presents statistical results of changes in climate indices in the Municipalities of Djougou and Ouaké

Table III: Statistical results of the change in minimum and maximum temperature in the project's target municipalities

Variables	p-value	R2 (%)	Pente (slope estimate)
TMax	0	55,2	0,026
TMin	0	36,3	0,015
CDD	0,059	6,6	0,484
CWD	0,398	1,4	-0,518
SDII	0,73	0,2	-0,007
R95p	0,407	1,3	-1,213
R99p	0,628	0,4	0,432

4.2- Evolution of standardized rainfall indices

Figure 2 shows the evolution of standardized rainfall indices.

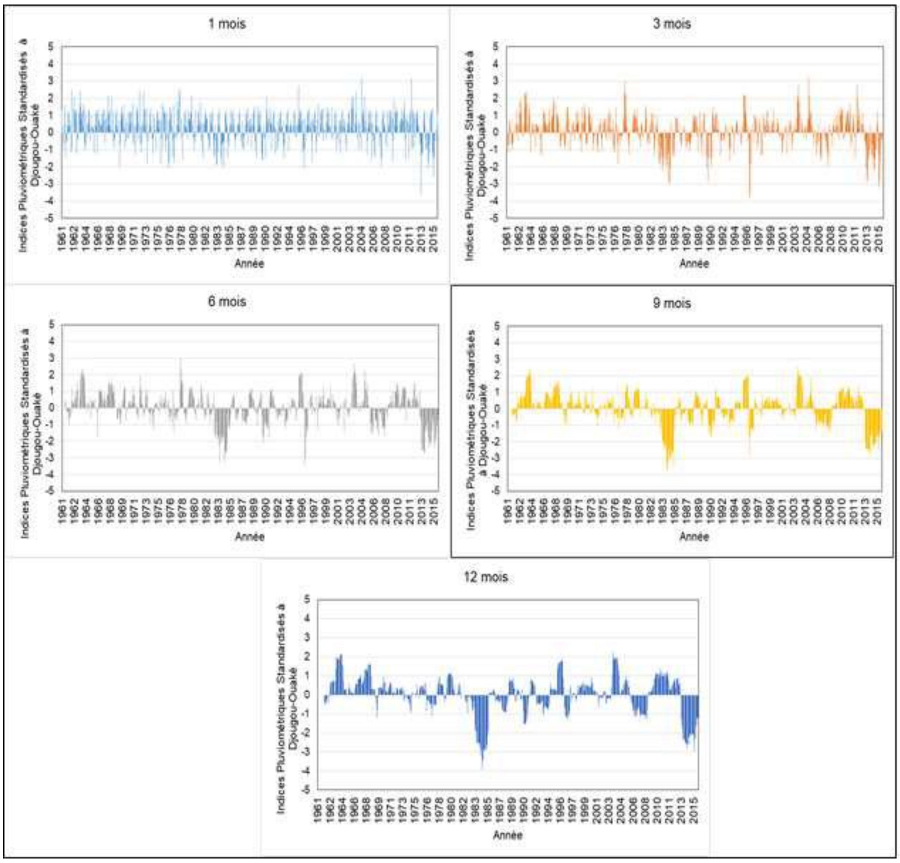

Fig 2: Rainfall Indexes Standardized in Djougou and Ouaké for 1 month, 3 months, 6 months, 9 months and 12 months with SPI_SL_6 (WMO, 2012)

The analysis of Figures 2 shows that as the time rate increases from 1 month to 12 months, there is an aggregation of information that could better characterize dry and wet periods in the municipalities. Thus, the originality of the analysis of rainfall indices with the approach of the SPI_SL_6 model of the WMO (2012) aims to disaggregate information relating to the characterization of standardized rainfall indices. Indeed, the analysis of the figure (2) indicates that in the target municipalities are more affected by drought episodes of 1, 3 and 6 months. This reflects the predominance of negative values recorded in SPI, 3 and 6. One could therefore conclude that women's groups are more affected by episodes of short-term droughts.

To better assess drought events, changes in maximum and minimum temperatures were calculated. Figure 3 presents statistical results of the evolution of the minimum and maximum temperature in the project's target municipalities.

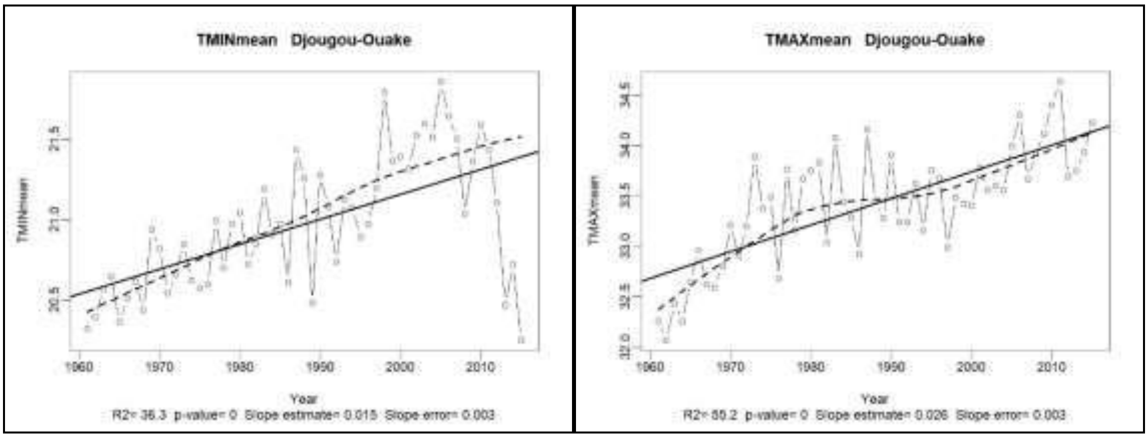

Fig.3: Interannual evolution of light and maximum temperature in Natitingou

Figure 3 shows that minimum and maximum temperatures show variability throughout the series with an upward trend in both municipalities. Minimum and maximum temperatures are actually rising in the various municipalities over the period 1961 to 2015. This is justified by the fact that the slope or value of the directing coefficient of the right equation is positive or even higher and significant for p-value = 0. This is justified by the fact that the R2 coefficient of maximum temperature determination is less than 40% in the municipalities of Djougou-Ouaké. Considering the values of the R2 coefficient of minimum temperatures, this research indicates that they are above 50% in the municipalities of Djougou-Ouaké. Since the increase in temperature has been a global phenomenon in recent decades (IPCC, 2018), it can therefore be attributed to the high anthropoisation and forms of land use, to deforestation especially in the municipalities of Djougou-Ouaké at the expense of cotton cultivation. However, plant cover plays a very important role in regulating ambient atmospheric temperatures and carbon sequestration that mitigates global warming (Weissenberger and Silva 2010, p.14). As for Ozer and Perrin (2014, p.11), rising temperatures can lead to risks to the agricultural calendar and food security problems. It should be remembered that the increase in temperature in the municipalities concerned are the source of extreme climatic events, including drought and floods that occur in these municipalities and make vulnerable human and environmental systems, and water-dependent activities against which women are most affected.

4.3- Evolution in the number of consecutive rainfall

Figure 4 illustrates the variability of consecutive dry days from 1961 to 2015 in the municipalities of Djougou and Ouaké.

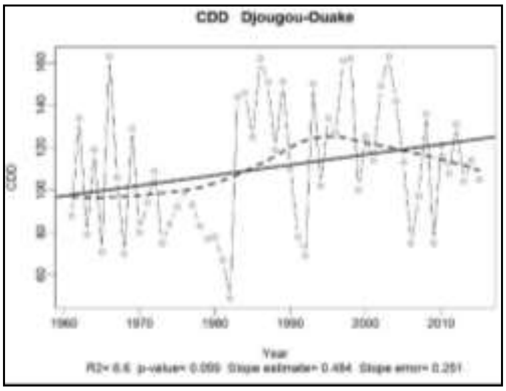

Fig 4: Consecutive Dry Day Variability (CDD) in project target municipalities from 1961 to 2015

The increase in consecutive dry days in the municipalities of Djougou-Glazoué is explained by the fact that the slopes (slope) are above 0 and are 0.059 respectively; 3,19; 0,48; 0.52 and 0.057 with a significance of the value of the value of which in the following order are: 0.78; 19,6 ; 0,059; 0,016; 0.82. However, the R2 values are not greater than 15% in the rainfall data of these municipalities. However, increased dry days can lead to heat waves, rainfall recession, water stress and desiccation and loss of pasture and the proliferation of diseases including much more infections observed in women. Rainfall data analysis shows a decrease in consecutive dry days (positive slope and above 0 with a meaning of 0.059 and 6.6, respectively). This confirms and explains this upward trend.

4.4- Evolution of consecutive rainy days (CWD) in target municipalities from 1961 to 2015

Figure 5 shows the evolution of consecutive rainy days in the municipalities of Djougou and Ouaké. Thus, the analysis of this figure 5 shows that, just like consecutive dry days, consecutive rainy days in municipalities vary in time and space.

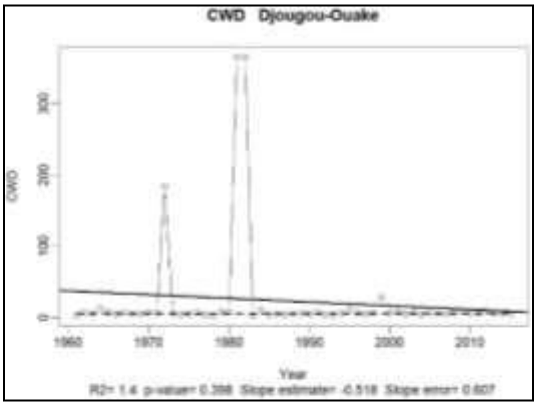

Fig 5: Consecutive Rainy Day Variability (CWD) in project target municipalities from 1961 to 2015

Statistical data including slopes relating to the guiding coefficient of the linear regression line, below zero with meaning of p-values equal to 0.752; 0; 0.398 corresponding respectively to the municipalities of Adja-Ouèrè, Athiémé, Djougou-Ouaké confirm that these municipalities are facing the decrease in consecutive rainy days, with R2 values ranging from 1.4. In the same context, Houndénou and Hernandez (1998, p.27), had previously reported that the decrease in rainy days can generate a significant decrease in heavy rains and a relative increase in low and moderate precipitation marked by a late start and an early end of the season rains. This situation is not without consequences for the agrarian landscape and agro ecological areas in which these municipalities are located.

According to Agossou (2008) and Koumassi (2014), excess rain is likely to induce risks of flooding, erosion in an anthropogenic environment, or in flood plains where people engage in agricultural activities, pastoralism, processing of agricultural products.

4.5- Evolution of the daily rain intensity index (SDII) in municipalities

Figure 6 shows the evolution of daily rain intensity (SDII) in the project's target municipalities.

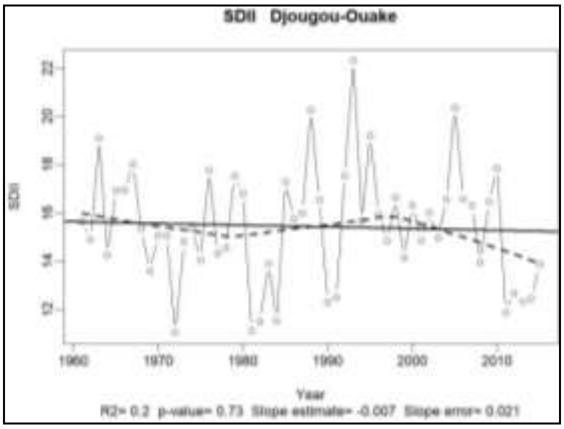

Fig 6: Variability in the Daily Rain Intensity Index (SDII) in the project's target municipalities from 1961 to 2015

The analysis of Figure 6 shows that the daily rain intensity index varies from year to year and they are either up or down in some municipalities. From 1990 on, an increase in the daily intensity of rain was observed in both Communes. These findings had already been made by H. Koumassi (2014) in the Sota watershed at the Coubérie outlet in northern Benin. Other authors such as E. Amoussou et al.,(2014,p.334); J. Kodja et al., (2018) indicated that this rise in daily rainfall intensity indices is related to the rainfall recovery recorded from the 1990s in sub-Saharan Africa including Benin.

Indeed, the increase in the daily intensity of rain observed in this study is explained by the fact that statistical analyses illustrate that the slope or slope corresponding to the direction coefficient of the linear equation right are on the one hand above zero with a meaning of p-values of 0.73. This has implications for societal issues in the various municipalities which increases the vulnerability of communities, producers, households and women's groups that invest in agro-pastoral activities.

4.6- Evolution of the corresponding rainfall heights to the 95th percentile in the target municipalities from 1961 to 2015

Figure 7 shows the evolution of the rain heights that correspond to the 95th percentile of rain in the municipalities of Djougou and Ouakéde 1961 to 2015

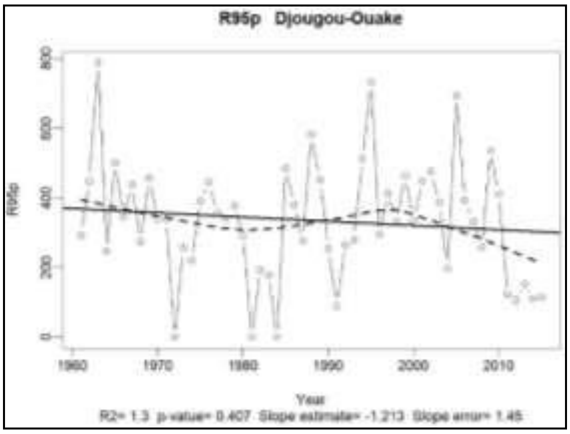

Fig.7: Variability in rainfall heights corresponding to the 95th percentile in target municipalities

The 95th percentile rainfalls are the characteristic rains of heavy rainfall events (Karl et al., 1999; Frich et al., 2002). Indeed, the analysis of Figure 7, leads to say that the heights of 95th percentiles show an upward trend in the Djougou-Ouaké. This can be attributed to the perverse effects of global warming. Very strong rain events are on the rise in the municipalities. The value of the R2 is 1.3%. Statistical information confirms that the rainfall heights associated with the 95th percentile of rain are decreasing. This decrease is illustrated by the negative slope with a meaning of p-values equal to 0.017 in the municipalities of Djougou and Ouaké.

4.7- Evolution of the corresponding rainfall heights to the 99th percentile in the target municipalities from 1961 to 2015

Figure 9 shows the variability of the rain heights of the 99th percentiles of rain.

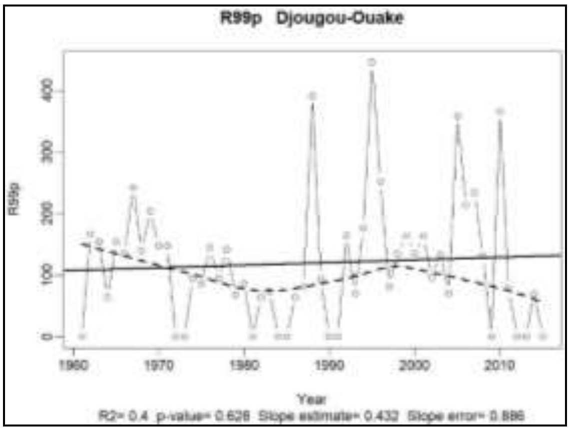

Fig.8: Variability in rainfall heights corresponding to the 99th percentile in target municipalities

The 99th percentile rainfall is the corresponding rainfall to extremely strong rainfall events. Thus, from the analysis of

Figure 8, it should be said that these extreme rain events show an upward trend in the municipalities of Djougou and Ouaké. The descriptive statistics clearly illustrate this increase by positive slope and levels of value significance of 0.628 and R2 of 0.4%, respectively. Of course, this situation is not without repercussions on human and environmental systems in the context of global changes where it is the rainfall accumulation associated with the various forms of land occupation that contribute to the outbreak of floods as in the intervention municipalities of this project.

V. CONCLUSION

The intensity and increasing frequency of extreme events affecting the world is only one aspect of the impact of climate change. Extreme weather events make us aware of the complexity of the effects of climate change and our differential vulnerability to extreme climate risks. Knowledge of rainfall extremes in the Municipalities of Djougou and Ouaké is a decision-making tool for decision-makers at various levels. These indices will make it possible to anticipate, prepare for the crisis and implement local measures.

REFERENCES

[1] CATTIAUX Julien, CHAUVIN Fabrice, DOUVILLE Hervé, RIBES Aurélien, (2020). Extreme Weather Events and Climate Change, Environment Encyclopedia, [ISSN 2555-0950]

[2] IPCC (2007). Climate change: impacts, adaptation and vulnerability. Working Group II's contribution to the IPCC's fourth assessment report. Cambridge, United Kingdom, Cambridge UniversityPress.

[3] BALGIS Osman-Elasha ,(2009). Impacts of climate change, adaptation and links with sustainable development in Africa, Unasylva 231/232, Vol. 60, 2009, 5 p

[4] FAO, 2011, West Africa and Sahel Disaster Risk Strategy FAO (2011-2013), 44p

[5] Koumassi D. H., (2014). Hydro-climatic risks and ecosystem vulnerability in the Sota watershed. PhD thesis from the University of Abomey-Calavi. 244 pp.

[6] C.FAYE, A.NDIAYE I. BAYE (2017) A comparative assessment of weather drought sequences by indices, time scales and climatic domains in Senega. J. Wat. About Sci.Vol. 1, No.1, (2017), 11-28 ISSN: 2509-0445 bhttp://revues.imist.ma/?journal=jwes

[7] Nora, Mohammed Keriati, and RehifAkila. (2017) Theme Contribution of climate variability in the context of desertification, case of the Djelfa region." 4

[8] WEISSENBERGER, Sebastian and SILVA, DelaineSampaio da. The Amazon- victim of climate change? (2010). . confines. Franco-Brazilian Geography Review/Revista Franco-brasilera de geografia,, No. 10.

[9] OZER, P and PERRIN, D (2014). Water and climate change. Trends and perceptions in West Africa. Water, environments and landscaping. A search for the territories, 227-245.

[10] HOUNDÉNOU, Constant and HERNANDEZ, Karine. Change in the rainy season in The Atakora (1961-1990). (1998) An example of drought in northwestern Benin (West Africa). Science and Planetary Changes/Drought, 1998, 9, No. 1, 23-34.

[11] AGOSSOU S.M. D. (2008). Adaptation to climate change: perceptions, local knowledge and adaptation strategies of producers in the municipalities of Glazoué and Savalou in central Benin. Cotonou: UAC, 173 pp.

[12] AMOUSSOU, Ernest, CAMBERLIN, Pierre, TOTIN VODOUNON, S. H., et al. (2014). Changes in extreme precipitation in the Mono watershed (Benin-Togo) in the context of climate variability/change. In: Climate: System - Interactions. 27th Symposium of the International Association of Climatology. Dijon, France: International Association of Climatology. 331-337.

[13] Kodja D. J., Vissin E.W., Amoussou E., and Boko M., (2013). Hydroclimatic risks and hydro-agricultural problems in the Ouémé Valley in Bonou (West Africa), in climate, Agriculture water resources from yesterday to tomorrow, acts of the 30th symposium of the International Climatology Association, Cotonou (benign).