Original Research Article

Impact of Rainfall Variability on the Streamflow of the Kara River Basin, Northern Togo

ABSTRACT

Water resources are affected by hydrological and climatological reactions in the Kara river Basin. The aim of this work is to analyze the dynamics of rainfall variability on the flow of the Kara River. Data was collected through documentary research and field surveys carried out among 82 correspondents. Data from the hydrological and climatological records (1955-2015) as well as socio-anthropological were used to conduct this research. The results were ascertained through state-pressure-impact-response model (SPIR). Year to year rainfall trends (1963 -2003) related to the stream flow showed that there has been low rainfall since the 1980s. This situation leads to extreme harsh flows of the Kara River located in the Kozah district. A look into the seasonal flow variability (1955-2015) showed that the average monthly flow figures over the years are very low from October to July (09 months) especially after the 1970s. This hydroclimatic dynamics have impacted the availability of water resources in the Kara basin located in the Kozah district. Indeed, the results of the annual changes in rainfall in relation to the flows of the Kara River showed a decrease in rainfall conditions from 1963 to 2003. As a result, people develop coping strategies that are ineffective.

Keywords: Northern Togo, Kara River, rainfall variability, water resources.

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1. INTRODUCTION

Water, «blue gold» and a source of vitality, is one of the major challenges of the 21st century. Although 70% of the world's surface is covered with water, only 25% is freshwater (Mélila, 2014; Mélila *et al*, 2018). The large African rivers, whose valleys are attractive areas, provide the framework for the implementation of various irrigation, watering, transport, energy, drinking water supply, and fishing activities (Mélila, 2017; Mélila, et al 2017).

Tra (1981) reported water is a resource that contributes to the domestic economy on a daily basis which it is the main pillar for developmental projects and programs. According to the Sahel and Sahara Observatory report (2007), it is a crucial source of energy production and contributes to economic development.

Since the 1970s, there has been a significant decrease in rainfall in West African countries (). This decrease in rainfall is characterized by a decrease of 20 to 30% (Servat et al., 1997; Mélila, 2017). This has resulted in a significant decrease in throughput, which has had an impact on the productions that depend on it (Atchadé, 2011). Such a drought has sometimes caused many rivers to dry up and have seen significant declines in their flows (Tossou, 2007).

Since the 1970s, the Kara region, like all other regions of Togo, has experienced high rainfall variability. This has a huge impact on water availability in the Kara River and on any activity of the riparian population (Lemou, 2007).

The district of Kozah, being the most developed and the most populated district of this region (Alidjao, 1995), the population experience water supply problems during the year, especially in the dry season. The Kara River is one of the major sources of water supply for the people living in the district (Mélila, 2014; Mélilaet al, 2017). However, the dynamics of hydrological deficits presented lead to socio-economic consequences on the population (Lemou, 2007). This raises a lot of scientific curiosity (Etene et al., 2015). It is in this context that it is necessary to put in place mitigation and adaptation strategies to the impacts of the dynamics of the river's low flows.

2. METHODOLOGY

2.1. Description of the study area

The Kara River watershed in the district of Kozah (Figure 1) is between 9°30' and 9°45' North latitude and 1°15' East longitude (Panawaï, 2001and Mélila et al., 2017). It is the capital of the Kara region.

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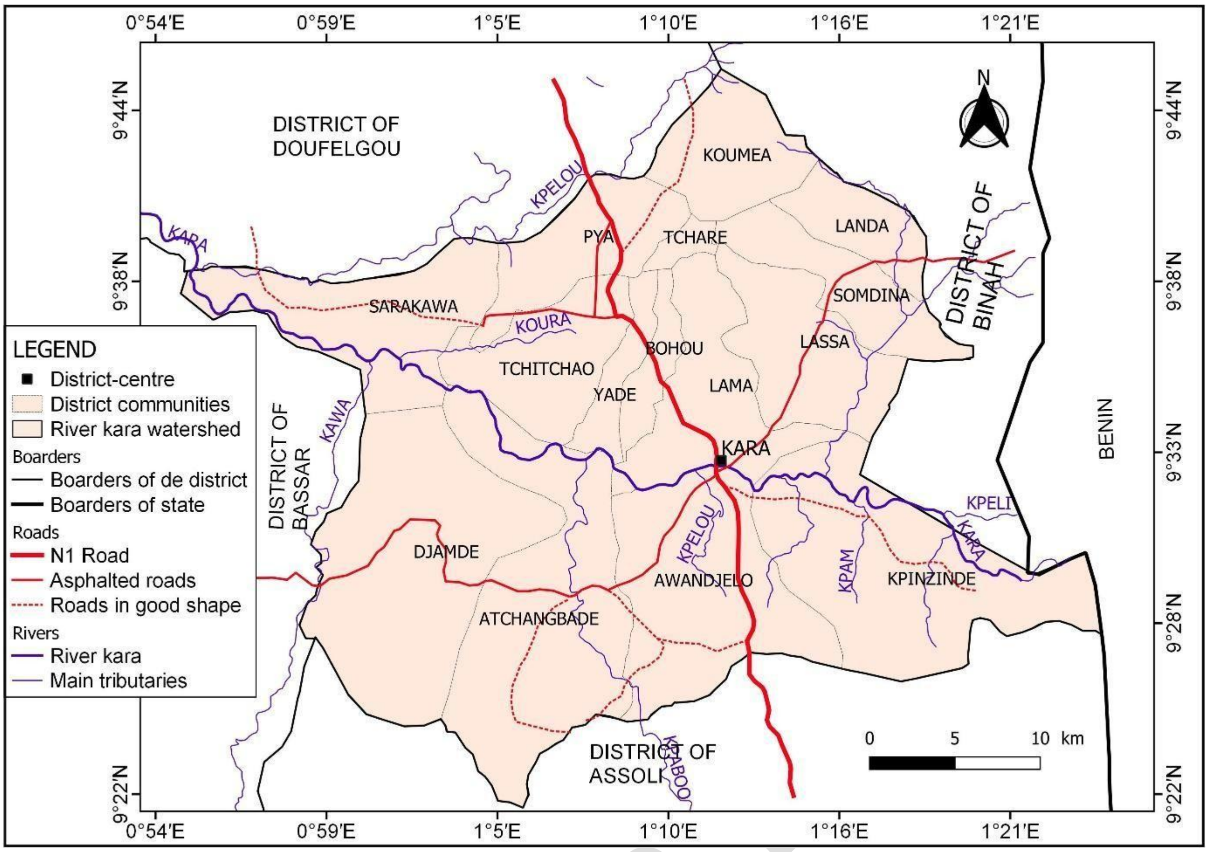

Figure 1: Geographical location of the Kara watershed.

The river Kara Basin in the Kozah district is bounded to the North by Doufelgou district, to the South by the Asoli district, to the East by the Binah district and to the West by Bassar and Dankpen districts. Describe indetail!!!

2.2.1. River System

The hierarchy in the hydrographic network is based on two main axes:

The Kara River, which is sourced from the Atakora mountains in Seméré, Benin, with an altitude of 400 m, flows through the district of Kozah from south-east to north-west (Mélila, 2014 and Mélila et al., 2017) and finally into the Oti River located on the of Togo Ghana boundary after flowing a total distance of 230 km on the Togolese soil (Alidjao, 1995).

The main tributaries are:

On the right bank: Tchinlow, Tomdéboua, Kpimbo, Pang, Kpelou;

On the left bank: Kokolou, Kpih, Agnaramlow, Kpélouwaï, Kpabo, Klikpen, Kawa.

2.2.2. Soils and Vegetation

In terms of soil, the district of Kozah is blessed with multipurpose soil (Mélila, 2014; Mélila et al., 2017; Mélila et al., 2018). The geological compositions encountered are basic to ultrabasic rocks of the upper Proterozoic of the Kabyè massif and the micaschists and quartzites of the pan-African orogenesis of the Atacora structural unit (Alidjao, 1995).

2.1. Data Used

Research data related to rainfall heights and temperature from 1961 to 2015 was sourced from the Directorate of National Meteorological service, Lomé as well as the Streamflow data (1955-2015) related to the Kara hydrometric station and demographic, socio-anthropological data. The data used in this research were climatological data (1961-2015), related to

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rainfall heights and temperature, were collected at the Directorate of National Meteorological service, Lomé; hydrological data (1955-2015) water flow rates at the Kara hydrometric station; demographic, socio-anthropological data.

2.2. Socio-Anthropological Method

Due to the geographical location of the targeted group, the method used for the main survey in 2016 was that of identifying the targeted group as well as indicating the places of the survey. The following criteria was used in the selection of these individuals:

- Be at least 25 years of age;
- Be a user of the water resources of the Kara River (stream operators: farmers, housewives, sand and gravel extractors located on the banks of the Kara River);
- Be acquainted with the area
- Be a head of a local organization which activity demands water from the river
- Be somebody working in the area the management or protection of natural resources

As far as the resource or wise persons are concerned, they must be at least fifty years old, having lived in the survey area for at least the last thirty years. The surveys were conducted in the form of interviews on the basis of questionnaires. The sample size was determined by Schwatz (1995).

X = Zα2p q/i2; with: X = sample size; Zα = 1.96 reduced deviation corresponding to a risk α of 5%; p = n/N; with p = proportion of retained populations (n) in relation to the total number of populations of the five (05) townships (N); q = 1- p;i = margin of error equal to 5%. The number of the population surveyed is 82 (Table 1). It was distributed among the five (05) town (Table 1).

Table 1: Sampling distribution

Town	Population of the communities	Targeted	P	q	i^2	$Z\alpha^2$	X	X*15/100
Atchangbadè	41	627	0.06	0.94	0.0025	3.8	85	12
Tchitchao	51	627	0.08	0.92	0.0025	3.8	111	16
Lama	79	627	0.12	0.88	0.0025	3.8	160	24
Kpinzindè	59	627	0.09	0.91	0.0025	3.8	124	18
Sarakawa	42	627	0.06	0.94	0.0025	3.8	85	12
Total	272	627	0.43	0.57	0.0025	3.8	565	**82**

Source : Work on the field, September 2016

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Table 1 shows the distribution of the surveyed populations. Five (05) communities were selected (Atchangbadè, Tchitchao, Lama, Kpinzindè and Sarakawa).

A survey questionnaire has been developed and given to the respondents. The survey was carried out in the communities that the Kara River flows through. The respondents were those who were in direct contact or engaged in an activity

Along the river.

The results of the data processing were analyzed through the PSIR (Pressure-State-Impact-Response) model.

2.3. Statistical Methods

The monthly and annual mean rainfall and hydrological heights of stream flow rates are calculated using the formula M = 1/n - (i = 1) n (xi), where M = mean, n = number of years. This mean made it possible to compare the monthly and annual values and see the hydro-climatic evolution over the chosen period. The annual variation in rainfall in the basin is calculated using the following formula: M = St/nt, where: M = average rainfall, St= sum of the total number of years considered and nt = number of years considered. The monthly flow rate variability is discussed in this section using the monthly flow coefficient (MFC). Thus, the MFC represents the monthly average flow ratio of the month under consideration to the annual average module. The formula for (MFC) is: MFC = Q/M where Q = average flow of the ego considered and M = module or annual average flow. The study of climate sequences was carried out the 1961-2015 series. The hydrological data covered the period 1955-2015.

3. RESULTS

3.1 Year-to-Year Change in Rainfall Totals

The research area is subjected in a whole to atmospheric circulation characterized by the alternative extension movement of two air masses (Mélila, 2014 and Mélila et al., 2017): harmattan and monsoon. The harmattan that characterizes the dry season evolves from December to February and the monsoon, characterizing the rainy season, starts from April to October. During the rainy season, there was a variation in rainfall over the same period. Similarly, for years in Figures 2 and 3, there were those in which the amount of rain is extremely large and those in which the amount of rain is small.

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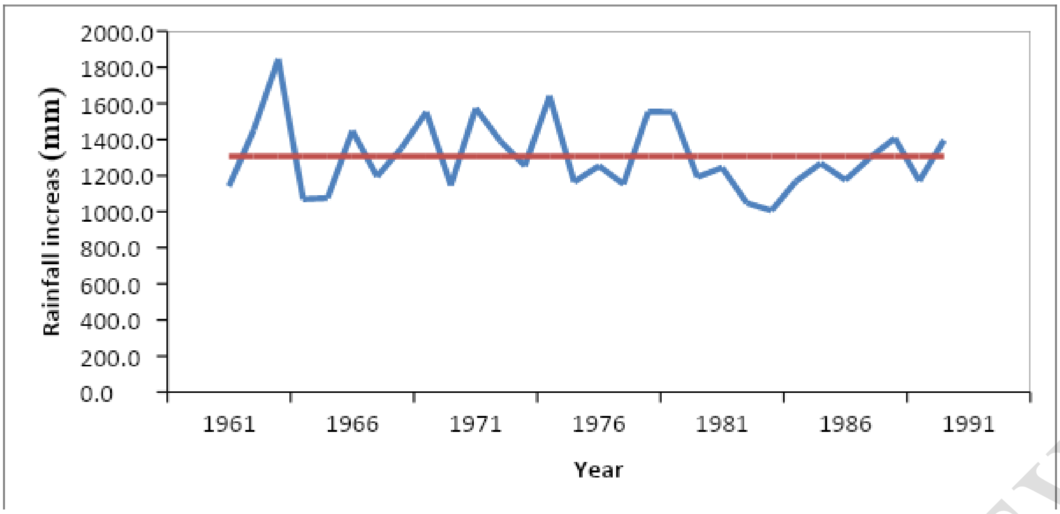

Figure 2: Year-to-year change in rainfall over the Kozah watershed from 1961 to 1990
Source: Directorate of National Meteorological service, Lomé (2016).

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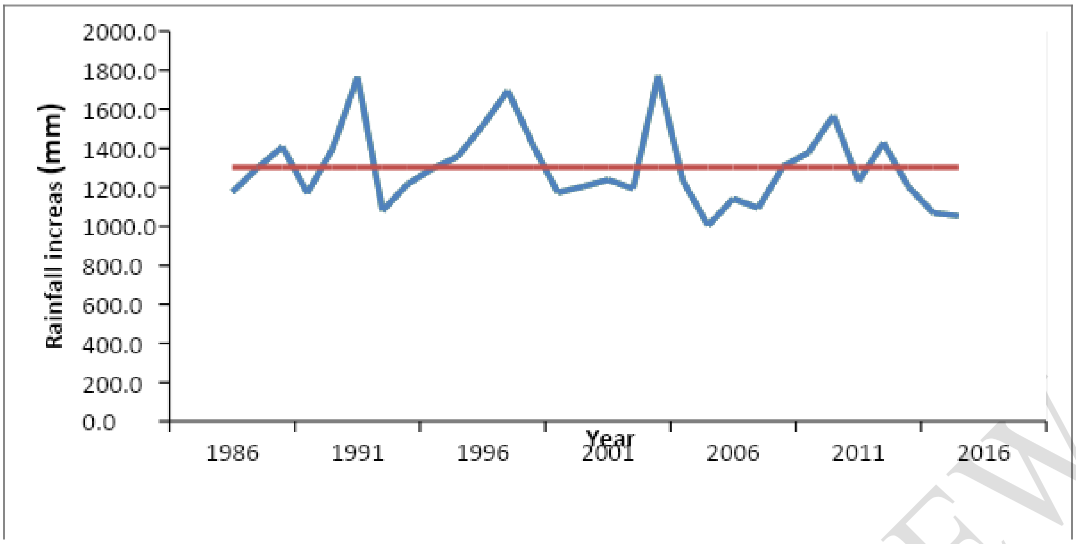

Figure 3: Year-to-year change in rainfall over the Kozah watershed from 1986 to 2015
Source: Directorate of National Meteorological service, Lomé (2016)

Figures 2 and 3 showed year-to year variation in rainfall over the Kara watershed in the Kozah district from 1961 to 2015. Looking at the average annual rainfall in Figure 2, there were variations from year to year. Deficit years were observed during the following years: 1961,

1964, 1965, 1970, and 1983. The years 1972, 1976, 1990 were average. The years 1979, 1997 and 1998 were surplus. In Figure 3, deficit rainfall was observed in the years 1992, 2005, 2007, 2014, and 2015. The years 1990, 1993, 1994, 1995, 2000 recorded an average rainfall. Surplus rainfall were observed in 1996, 1997, 1998, 2010, and 2012.

From 1995, the rainfall situation marks a favorable return. But generally, the station presents a deficit situation. This rainfall deficit therefore affects the availability of water in the bed of the Kara River.

3.2. Dynamics of Year- to-Year Flow Variability in the Kara River

The low water levels in the Kara River were a result of the drying-up of the minor bed with the exception of a few pond-shaped areas in the talweg or at best reduced to a mesh of water nets in the interlaced channels (plate 1). This is the time of great water stress for off-season crops (Lemou, 2007and Mélila et al., 2017).

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Plate 1 : Drying up of the Kara River at Tchitchao
Shooting: S. Mélila, December 2015

Plate 1 shows the dry Kara River almost completely at different places, showing rocks. This drying out is due to rainfall during a long period of the year. The flow variability analysis showed the year to year variability of the Kara River flows (Figure 4).

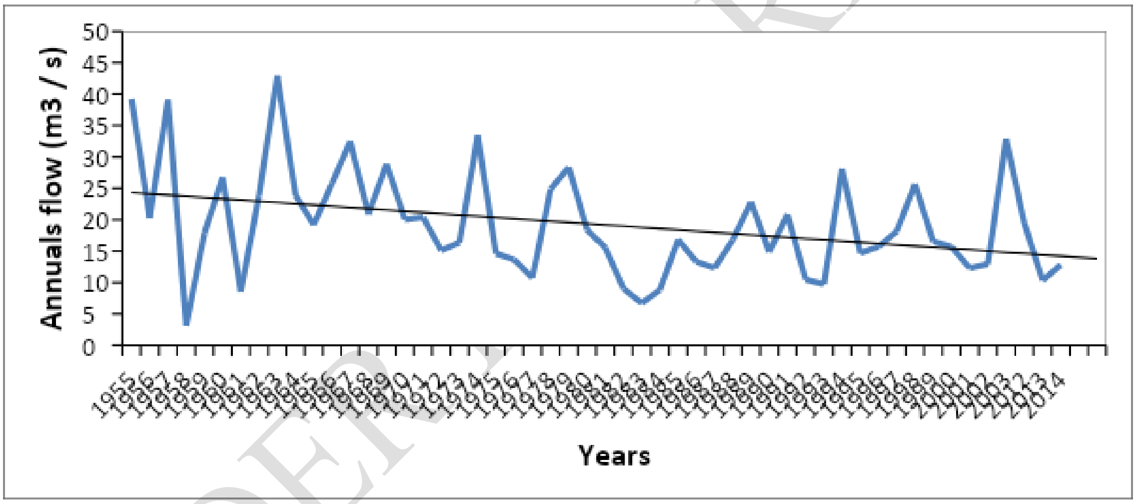

Figure 4: Dynamics of year-to-year stream flow variability in Kara River from 1955 to 2015
Source: Lomé Water Resources Directorate (2016)

Study of figure 4 revealed that high water years (1955 with 39.22 m3/s, 1957 with 39.11 m3/s, 1963 with 42.89 m3/s) are poorly represented, from years with average flows (1956 with 20.25 m3/s, 1960 with 26, 73 m3/s, 1966 with 25.76 m3/s) and low-flow years that are larger, such as (1972 with 15.11 m3/s, 1975 with 14.61 m3/s, 1976 with 13.65 m3/s, 1977 with 10.73 m3/s, 1983 with 6.71 m3/s, 1993 with 9.72 m3/s, 2013 with 10.32 m3/s, 2014 with 12.79 m3/s).

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The variables of annual flows decreased moreover the years as the rainfall quantities recorded during the same period. This observation was made on monthly flow (Figure 5), during this observed period.

3.3. Monthly Flow Variability

Monthly abundance rainfall between June and October in Kara, feeds the flow. Rainfall is involved in tropical stream flow (Lemou, 2007). Periods of high and low water were then observed. The monthly flow coefficient (MFC) was used to define the different periods of flow changes during the year (Figure 5).

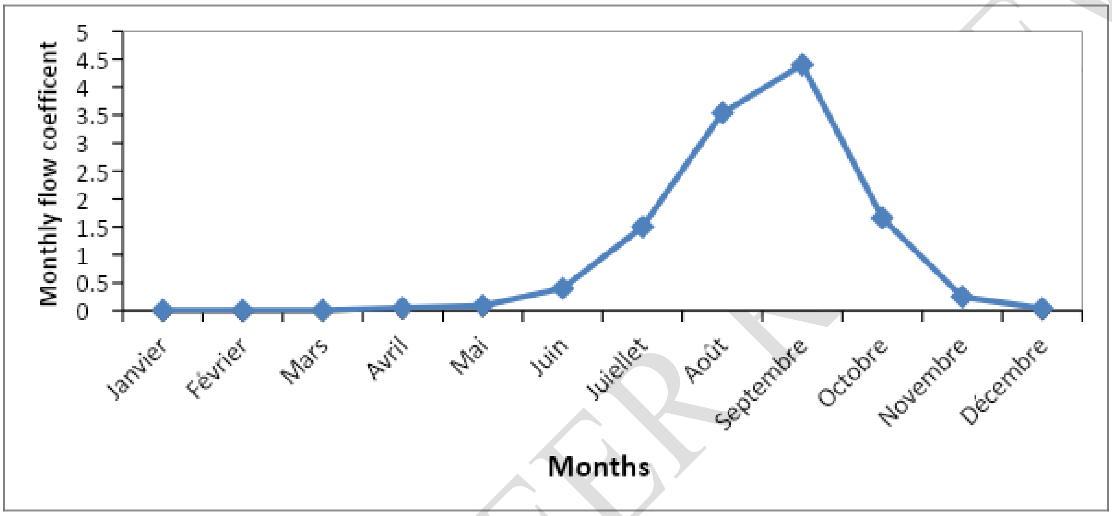

Figure 5: Monthly Flow coefficient (MFC) 1955-2003

Source: Directorate for Water Resources, Lomé

In the seasonal evolution of monthly average flows according to Figure 5, different phases were recorded. The rise of the waters begin in June. The month of July corresponding to an effective installation of the rainy season, there was a noticeable increase in the rise of the waters. The period from August to September is characterized by a sharp rise in flow, corresponding to the maximum rainfall. The decline begins in October. The end of the rainy season during that month explains this decrease in flow until December. The period from January to March is characterized by a slow drying up of water. The lowest flow variables are observed from January till May ending. From the observation of Figure 5, there are two essential phases in the evolution of the monthly average flow. A period of water rising from July to October which corresponds to the rainy season and a period of low water from November to June characterized by the dry season. The ever-increasing rainfall deficit in recent years has resulted in a general weakening of the hydrological regime and a shift from

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perennial to intermittent runoff, as evidenced by the very low monthly flow values for the period 1955-2003.

3.4. Rainfall Relationship and Flows

The rainfall flow relationship is illustrated by rainfall data and annual average flows from the Kara Rainfall Station. The choice of these two parameters to highlight the influence of climate on flow is dictated by the fact that "the measured flow rate at a given point in a stream was representative of the average rainfall activity over the entire surface of the corresponding watershed." Mélila (2017) This relationship allows "to develop a warning period for flows arriving at measurement stations especially when agricultural hydro-development works are built on the river systems of the basin," Lemou (2007), as shown in Figure 6.

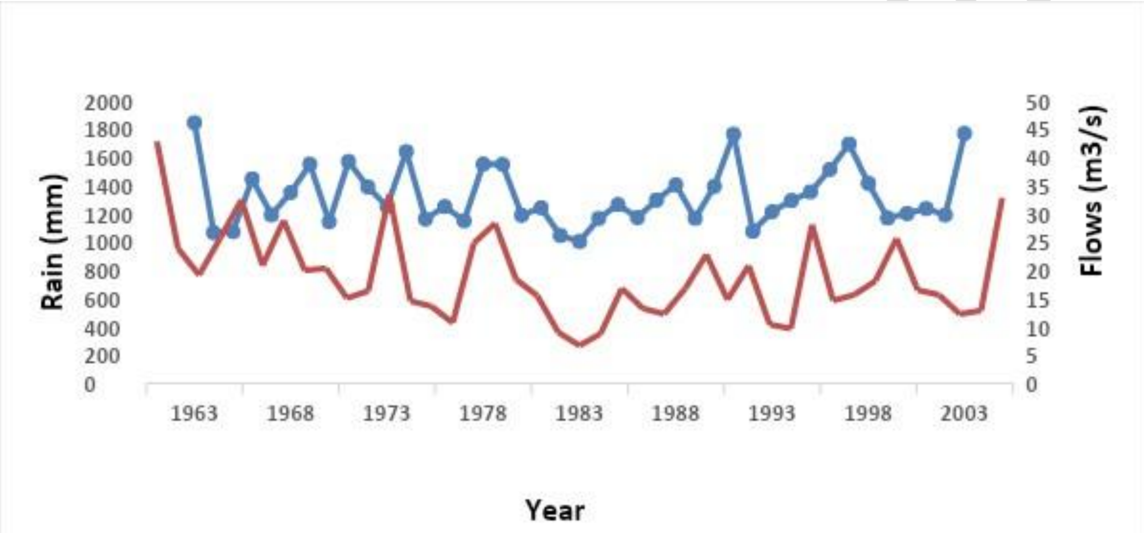

Figure 6: year to year change in rainfall compared to flows of the Kara River from 1963 to 2003.
Source: Directorate of Water Resources and National Meteorological service, Lomé (2016)

The analysis in Figure 6 showed that there was a relationship between low rainfall and river deficit and their abundance. The 1960s recorded an abundant rainfall corresponding to an abundant flow. The 1970s were characterized by an alternation between a deficit and a surplus in rainfall. The period from the 1980s to the 2000s, was the period with the highest rainfall deficit, making it the period with extreme harsh flows.

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In short, the Kara River does not have a very large flow. The increase in rainfall conditions and the weakness of the flow during a long period of the year justify the importance of the depletion of the water resources of this river in the Kozah district This same hydro-climatological observation was made by the residents along the Kara River. According to 94% of the population, the climate of the Kara watershed has changed in recent years. According to them (67%), before the 1990s, the start of the rainy season was around the month of April. Before the 2000s, this start has progressed and is centered between May and June. After the 2000s, till now the beginning of the rainy season varies between June and July depending on the year. Analysis of the monthly flow coefficients for 1955-2003 therefore confirms this population assumption.

4. DISCUSSION

The economy of the people bordering the Kara River is mainly based on the availability of water resources. However, since the 1980s the hydro-rainfall situation has been decreasing as the years go by. This appreciation was made by Alidjao (1995) and 87% of contact persons. The analysis of the year to year change in rainfall in relation to the flows of 1963-2003 explains the importance of this reduction of water resources in the Kozah district. This general decline in water resources is therefore in line with the decrease in rainfall, especially over the last three decades. An analysis of the seasonal variability of flows from 1955 to 2014 showed that before the 1970s, low flows were recorded from January onwards. From the 1970s until date, these low flows now begin in October and are distinguished by a harsh low flow for 9 consecutive months during the year. This extends with the rainfall crisis over the years as shown by Mélila (2014). Rainfall and hydrological trends also vary in the same way. This leads to 89% of the population decline of the economy of the residents of Kara. This situation has an impact on the availability of water resources in the Kara river and on the vegetable production by the residents, as shown by Alidjao (1995) and Lemou (2007). Faced with this situation, the people living around the Basin in the Kozah district develop adaptation strategies that are insufficient and ineffective. These strategies are expressed in particular through the realization of water dams at the level of pools, drilling of deep wells at home and at the level of vegetables farming, the use of new varieties of seeds with short cycles and practices adapted to climatic whims, the adjustment of the calendar of agricultural activities and the change of these activities for other income-generating activities. These different strategies are not very effective, hence the decline in returns.

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5. CONCLUSION

This research analyzed the impact of rainfall variability on the flow of the Kara River in the Kozah district. The study of the year to year and monthly variability of the hydro-climatic regime over the period 1955-2015 showed that the study area is under the influence of water deficits. The calculation of the monthly flow coefficients made it possible to define the different periods of change in flow during the year; It appears that the beginning of the decline in water in the Kara River begins in October, which marks the end of the rains in this area. The highest levels were recorded between January and June. The period from July to October corresponds to the period of intense rains, so high water in this river. In order to better outline hydro-climatic phenomena in future research, a multi-criteria study will be carried out integrating all the physical and human factors that determine the availability of water resources in the Kara basin.

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