WATER SCARCITY IN AFRICAN CITIES: ANTHROPIC FACTORS OR CLIMATE CHANGE? CASE OF BOUAKE (CÔTE D’IVOIRE)

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KEYWORDS: Water resource scarcity, water shortage, African city, surface water, geospatial mapping, land use, Loka river Basin, Côte d’Ivoire

ABBREVIATIONS:
DW: Drinking water
SPI: Standardized Precipitation Index
SODECI: Water Utility

ABSTRACT

The second largest city of Côte d’Ivoire Bouaké and its surroundings experienced in 2018 an extreme water shortage. This environmental disaster left about 1.5 million inhabitants without drinking water. The water shortage resulted from the drying up of the Loka dam which is the main source of drinking water for this region. This disaster was unusual because water resources scarcity should not occur in this region.

In West Africa in general, especially in Côte d'Ivoire, a correlation between water scarcity and climate change can be made. Land use which reflects anthropic activities can be components for understanding river basin drainage. A hydrological change such as water scarcity could be linked to land use.
The objective of this study was to assess the impact of anthropic activities and rainfall variation related to climate change on water resource scarcity to meet the water demand of the city of Bouaké and its surroundings.

Using the Standardized Precipitation Index, our study assessed rainfall variation change in the Gbéké region. Anthropic activities assessed through land use were analyzed from satellite images and fields surveys.

From 1980 to 2016, the SPI index presented an overall wet period except in Bouaké. Additionally, land use changes showed anthropic activities impact; quarries might have been one of the main reasons of the drying up of the Loka dam hence the water shortage.

This water shortage, resulting from inadequate river basin management is calling for research on water governance, water management and water policy.

1 INTRODUCTION

The lack of drinking water supplies is the subject of several problems around the world. Water availability of is one of the basic human needs to be met in adequate quantity and quality (UNICEF / WHO, 2017). Water helps to improve social well-being by promoting growth for all. Unfortunately, water resource is strongly affected several factors including climate change and human activities.

Climate variability specifically rainfall, in West Africa in general, and especially in Côte d'Ivoire, is no longer to be proven. For a region already impacted by droughts such as West Africa, this issue is crucial (Soro et al, 2013).

Land use changes according to the farming habits of agricultural land. It is a key variable for understanding the environment and regional planning (Foody, 2002; in Sarr, 2010). In addition, it has become essential in most mapping inventories and environmental monitoring (Ouattara et al., 2006).

The Loka dam, Located, in the Gbéké region of the country is the main source of drinking water for Bouaké the second largest city of Côte d'Ivoire. According to the literature, the region is affected by climate change. In 2018, the city of Bouaké and its surrounding communities experienced a severe water shortage. This shortage episode was due to the drying up of the water resource, the dam in the Loka river. This disaster was unusual because water resources scarcity shouldn't occur in this region.

As a result of the shortage, about 1.5 million inhabitants were left without drinking water leading to a major public health issue. This episode affecting Bouaké and its region has been the subject of several national and international press articles (Le Monde, 2018).

It was reported that West Africa has had reduce rainfall since 1970 as the consequence of climate change. Water scarcity is linked to climate change, therefore strong correlation will be made between water scarcity and climate change. However, land use which reflects anthropic activities appear to be key factor of understanding river basin drainage. Therefore, hydrological change such as water scarcity could be linked to land use.
The objective of this study was to assess the impact of anthropic activities and rainfall variation related to climate on water resource scarcity to meet the water demand of the city of Bouaké and its surroundings.

1. INTRODUCTION OF THE STUDY AREA

The large Bandama River basin is divided into three sub-basins named as “Bandama rouge”, “Bandama blanc” and “N’Zi”. The Loka river basin (Figure 1), selected for this study is a sub-division of the Bandama Blanc river basin. Located in the Gbêkê region, it covers administrative departments: Bouaké, Botro and Sakassou. More precisely, it is surrounded by four major towns: Bouaké in the northeast, Diabo in the north, Languibonou in the west and Sakassou in the south. This river basin is located between 7° 28'30" and 7° 39'0" north latitude and between 5° 21'0" and 7° 10'30" west longitude. Its catchment area is 762 km² and has a perimeter of 65.21 km.

The climate of this region is the transitional sub-equatorial type. It has four seasons including two rainy seasons and two dry seasons. The average annual rainfall is 1200 mm. The hydrographic network is relatively dense and flow from North to South. The Loka river flows across its water basin. It is fed upstream and downstream by tributaries. The Loka river is a tributary of the Kan River which merge with the “Bandama blanc (Main River). The Loka river basin has a top altitude of about 400 m.

A dam is built 10 km downstream to the river. Located at 20 km west of Bouaké, this dam is the main water resources for drinking water production. It operated by the water company of Côte d’Ivoire (SODECI).

Figure 1: Location of the study area and the Loka dam

2. Drinking water supply in and around the city of Bouaké

The city of Bouaké and its surrounding towns receive water supply mainly from surface water of the Loka dam. The Loka dam was built in 1976 on the bed of the Loka river. Its sustainable capacity is estimated at about 25,000,000 m³ / year.
The Loka dam supplies a drinking water treatment plant (the Loka station) that serves multiple localities. Among them, Bouaké, Botro and Sakassou are the mains. The new water treatment plant built in 2014, increases the overall drinking water capacities to 1300 m$^3$/hr and 30,000 m$^3$/per day.

The drinking water treatment plant on the Loka dam provides about 80% of the water service of Bouaké and its surrounding. Additional water resource comes from small dam and deep boreholes flowing from 2 to 21 m$^3$/per h. Totally, surface water provides 92% of the city’s water resources while 8% for groundwater. Drinking water access of the community is 72 %. An on-going governmental project aims to improve drinking water access throughout the region.

However, full access to drinking water is a challenging issue. Previous years, water shortage occurred with some of them which lasted several days. In 2017, 468 water shortage episodes were reported. (SODECI). These problems come from power cut, broken pipes, maintenance issue and an increasing water scarcity. On the other hand, the region’s DW distribution network does not extend to all localities. Thus, to address this water shortage, populations refer to alternative water sources with some of them unsafe such as boreholes, wells, surface water which dry up during the dry season.

3. Shortage of drinking water in the city of Bouaké and its surroundings

Water shortage in the study began in January with untimely water supply outage. They became worst April. In order, to meet the population’s water demands, the local authorities provided water tankers (figure 2). (Our surveys, 2018). DW from deep boreholes and surface water Lake Kan (was used to fill the tankers. The operational management of the process was lead by National Drinking Water Agency -ONEP and the Water company SODECI. The alternative water delivery was made at different places such as schools, hospital, neighborhoods, community leaders and surroundings cities (Figure 2)

Figure 2: Drinking water supply

2 METHODS

The rainfall characterization was used to assess climate change. This rainfall characterization was done using the Standardized Precipitation Index (SPI) created by T.B. MCKEE et al. (1993) quoted by Diomande et al., (2014). This Index allow the study of rainfall over the period 1980-2018. The rainfall data from SODEXAM (Airport, Aeronautical and Meteorological Exploitation and Development Company / National Meteorological Department) was used.
The SPI calculation was done according to the following formula:

\[ SPI = \frac{(Xi - Xm)}{Si} \]

- \( Xi \): the cumulative rainfall for year \( i \);
- \( Xm \): average rainfall observed in a given period.
- \( Si \): the standard deviation of the annual rainfall recorded for a given period.

This index defines the severity of drought in different classes (M. Bergaoui and A. Alouini, 2001; S. Ardoin-bardin et al, 2003; S. Ardoinbard, 2004; A. Ali and T. Lebel, 2009; T. Lebel and A. Ali, 2009), quoted by Faye et al, 2015. Negative annual values of SPI relative to the chosen reference period indicate a drought while positive values indicate a wet situation.

**Table 1: Classification of drought in relation to the value of the Standardized Precipitation Index (SPI)**

<table>
<thead>
<tr>
<th>SPI Range</th>
<th>Degree of drought</th>
</tr>
</thead>
<tbody>
<tr>
<td>spi &gt; 2</td>
<td>Extreme humidity</td>
</tr>
<tr>
<td>1 &lt; spi &lt; 2</td>
<td>High humidity</td>
</tr>
<tr>
<td>0 &lt; spi &lt; 1</td>
<td>Moderate humidity</td>
</tr>
<tr>
<td>-1 &lt; spi &lt; 0</td>
<td>Moderate drought</td>
</tr>
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<td>-2 &lt; spi &lt; -1</td>
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</tr>
<tr>
<td>spi &lt; -2</td>
<td>Extreme drought</td>
</tr>
</tbody>
</table>

The methodology to assess the impact of anthropic activities was done on land use. Through geospatial mapping and field surveys, in order to identify all activities likely to impede the water flow from the river basin to the river, ultimately to the Loka dam.

Satellites images provided by the department LHCTE have been used for several years for land use mapping. Images were taken in the month January during the dry season allowing better image quality (devoid of clouds). These satellites are Landsat MSS (1986), ETM + (2002), OLI / TIRS (2017) and SENTINEL 2A (2018). In order to better understand the dynamics of land use, all these images were taken in the month of January. The aerial photos were used to report field survey data. These data mainly include, quarries pictures and GPS position according to the hydrological system. Finally, satellites images were used to evaluate the dam surface from 1986 to 2018.

### 3 RESULTS

1- **Assessment of climate change**

The annual rainfall values of the standardized precipitation index from three weather stations in Bouaké, Botro and Sakassou are displayed in [chart 2](#). These stations are located almost evenly along the Loka river basin.

Our finding in this study, shows over the decades 1980-1990, a positive SPI value often above 1 in Bouaké, Sakassou and Botro. This is perceived by a wet period for three consecutive years in Botro.

Theses SPI indices between 1980 and 2016 showed a positive trend in Botro and Sakassou reflecting an overall wet period. However, the weather data of Bouaké region displayed no humid nor drought trend, revealing an inconclusive SPI interpretation.

Despite previous findings on climate change evidence in the large Bandaman river basin, our study reveals that climate change does not significantly affect rainfall. Our findings are different than the ones reported for the large Bandama river basin. This can be explained because the study was only conducted in a sub division river basin which is not impacted by rainfall reduction in others areas of the large Bandama river basin. If over the decade rainfall reduction is not obvious, this is not an alarming situation. Nonetheless, it should raise awareness to the fact that this might be a new trend especially with the case of Bouaké.

**Chart 2: Interannual evolution of rainfall in the Loka watershed from 1980-2018**
2- Study of land use in the river basin

Analysis of land use (fig 3) from satellite images from 1986 to 2018 revealed the following observations.

![Land use maps 1986, 2002, 2010, 2018](image)

**figure 3: Land use around the Loka dam from 1986 to 2018**

Analysis of the land use presented here shows that there is a noticeable variation in the surface area occupied by crops and fallows, from 15.77% in 1986 to 32.07% in 2018 (Figure 3). While water resources have experienced a constant decrease, from 2.08% in 1986 to 0.41% in 2018. It is the same trend concerning forest surfaces which felt from 13.55% in 1986 to 10.74% in 2018.

In addition, concerning the water river basin, the savannah which was about 16.81% in 1986 was estimated at 5.27% in 2018. Finally, the spatial occupation of bare / used soils has increased from 10.24% (1986) to 43.71% (2018). In general, the land use proportion of the different categories (bare land and habitation, crops and fallows) increase compare to the other classes. Indeed, the land use rates have a major influence on the hydrological and water resources cycle (Liang et al., 2012; Zahabiyou et al., 2013). This increase in the proportion of land use affects water resources through the water retention capacity of the soil (Zhou et al., 2013). In this study, water resources have experienced a constant decrease from 2.08% in 1986 to 0.41% in 2018. It should be noted that the increase in forest classes from 2017 can be explained in the study area by expanding mangoes and cashew orchards. In fact, their spectral signature by aerial view can be associate with the ones from the natural forest.
**figure 4: Land use around the Loka dam from 1986 to 2018**

From satellite images analysis of land use (fig 3) over the period of 1986 - 2018 is appear that the vegetation is reducing and replace by crops, fallows, bare soils and dwellings and built-up areas. There is a rather remarkable change in time and space.

Field surveys revealed several sand mining in the Loka water basin. Indeed, one of the important human activity is the quarry activity, ie the extraction of sand as a building material. The increasing sand quarries reflects the accelerated urbanization which is proper to developing African cities.

Field survey around the Loka dam revealed that most of the quarries are mostly located by the rivers and upstream of the dam (figure 4). We observed in some areas the geomorphological landscape modification and destruction of the vegetal cover. We noted from these observations that most of the quarries hold large amounts of water (Figure 5). Therefore, they decrease the runoff coefficient of the water basin and reduce water flow to the Loka dam. From this finding, we can say that these the combined effect of quarries and evaporation contributed to the dam surface reduction. However, we have not assessed the cumulative surface area of the quarries, nor the volume of water likely to be retained by this mining activity to evaluate the phenomenon sweep.

Indeed, the activities and processes induced by natural and anthropogenic factors, not only modify upstream environmental variables (such as landcover and land use), but also affect the downstream environment in terms of water availability. (Nepal and Shrestha, 2018).
3- The Loka river dam surface variation

The spatial analysis of the Loka dam from 1986 to 2018 showed an overall regression of water surfaces from 2.08 km² (1986) to 0.41 km² (2018) (Figure 6). Loka river dam surfaces analysis shows an overall regression of these water over these 32 years. From 2014, the expansion of the Loka water treatment plant increased the DW production with capacity of 8000m³/h. This increase volume of water collected from the dam could have contributed to its significant surface reduction in 2018.

The gradual drying up of the Loka dam began in February 2018 and was completed in April 2018. The estimated volume of water in the dam was to less than 2 million m³. This environmental disaster resulted in an extreme water shortage in Bouake and its surroundings.
These analyses showed that water, forest and savannah have disappeared over time; while crops, fallows, bare soil and buildings have increased in river basin. In addition, the occurrence of several quarries holding large quantities of water was observed upstream to the river and around the Loka dam. The land use changes, specifically quarries, might have been one of main reason that cause the drying up of the Loka dam and consequently the water shortage.

**Conclusions**

In 2018, Bouaké city of Côte d’Ivoire with about 1.5 million inhabitants experienced an extreme water shortage. This water resources scarcity resulted from the drying up of the Loka dam which is the main source of drinking water for this region and its surroundings.

This environmental disaster was followed by public health issue because of the population was facing an unusual lack of drinking water situation.

Using rainfall Standardized Precipitation Index, our study assessed climate change in the Gbêkê region. SPI indices between 1980 and 2016 showed a positive trend in Botro and Sakassou.
departments reflecting an overall wet period. In Bouaké department, SPI index displayed no humid nor drought trend, revealing an inconclusive rainfall change interpretation. If over the decade rainfall reduction is not obvious, this is not an alarming situation. Nonetheless, it should raise awareness to the fact that this might be a new trend especially with the case of Bouaké.

Land use analysis from satellite images and fields surveys showed that water, forest and savannah have disappeared over time; while crops, fallows, bare soil and buildings have increased in river basin. In addition, the occurrence of several quarries holding large quantities of water was observed upstream to the river and around the Loka dam. The land use changes, specifically quarries, might have been one of main reason that cause the drying up of the Loka dam and consequently the water shortage.

This water shortage, is the result of inadequate river basin management. According to the 2006 Human Development Report, water scarcity is not rooted in the physical availability of water, but in unbalanced power relations, poverty, and inequality.

This issue of the Loka river basin and dam calls for research on water shortage and scarcity to continue towards the inclusion and scrutiny of concepts of water governance, water management, water policy, environmental integrity, and water's role in societal and economic development.
References


