

Growth of the City of N'Djamena and Recurrence of Flooding in the 9th District

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Abstract:- Cities in tropical Africa are growing rapidly and are spreading over large areas. Settlements are developing on floodable land, aided by rainfall deficits. Since the 2000's, these cities have been experiencing perpetual flooding due to increased rainfall in the region. Located at 12° 0' 44" and 12° 6' 30" North latitude and 15° 1' 59" and 15° 9' 47" East longitude, the 9th district of N'Djamena does not escape this situation, since it experiences recurrent flooding. This contribution aims to highlight the deficit in policies to produce building land in urban areas. The method is based on the exploitation of various sources of information including demographic, climatic, hydrological, and field observations. This has made it possible to understand that population growth is accompanied by anarchic expansion of the city, the most well-known characteristics of which are the illegal acquisition of building land and settlement on marginal land thanks to the multiplication of dry years during the period from 1980 to 2000. With the return of the wet years, the 9th district experiences cyclical flooding. As a result, the dwellings located in the depressions are flooded or collapse. The damage caused is enormous. The public authority has erected a dike to protect the inhabited areas. Similarly, the inhabitants take measures to build dikes around the houses during floods to prevent them from collapsing. Canals are dug to drain away rainwater. Households in the most vulnerable areas take refuge in the district's schools. Thus, land practices are the main source of uncontrolled expansion. The public authorities are partly responsible for this anarchism because land control through urban planning and the official production of building lots is the only means capable of dissuading illegal developers. To remedy this situation, it is sufficient to promote the official production of building lots, to control anarchic installations in the urban perimeter, to improve the protective dike of the district and to set up rainwater drainage networks in flood-prone areas.

Keywords:- N'Djamena, 9th District, Urban Growth and Flooding.

I. INTRODUCTION

Cities are growing and the proportion of the population added to them is significant. 54% of the population lives in urban areas, a proportion that is expected to rise to 66% by 2050 [1]. Urban land use growth is outpacing population growth by 50%, which is expected to increase the global built-up area by 1.2 million km² by 2030 [2]. This proportion of the urban population in sub-Saharan Africa is accentuated by the pressures of poor climatic conditions that force rural inhabitants to migrate to urban areas [3]. In urban areas, due to population growth and lack of adequate urbanization plans, populations, driven by extreme poverty and uncivil behavior, settle in anarchic ways [4]. They live on marginal lands, usually former peri-urban flood depressions, which have dried up during waves of drought. This is due to the unavailability of buildable space in the city center, the high cost of the few plots of land available for purchase, and ineffective urban policy.

In recent decades, several countries around the world have been severely affected by extreme weather events such as droughts and extreme rainfall [5]. Climate change is often indexed by scientists when extreme weather events are observed [6]. All agree that these phenomena are usually accompanied by catastrophic situations such as floods and droughts that cause material and human damage. The recurrence of certain natural disasters is a matter of public concern [7].

Human settlements are becoming increasingly vulnerable to the adverse effects of this change, whether it be the increased frequency and intensity of weather events, extreme temperatures, or flooding [8]. This climate change is linked to the increase of greenhouse gases (GHGs) in the atmosphere due to human activities such as the use of fossil fuels for heating, electricity, and transport, as well as industrial processes and land use changes [9]. Extreme weather events are now occurring more often with some severity [10] and will increase in severity, if not seasonally, and according to the geographical environment [11]. These

events are proving disastrous for urban communities without sustainable solutions to combat them [12].

Since the middle of the 19th century, Chad has experienced rising temperatures and falling rainfall [13]. On the other hand, when the atmosphere is warmer, its capacity to retain water vapor increases, leading to episodes of heavy rainfall [14]. The districts of cities such as N'Djamena, located in depressions, have begun to feel the adverse effects of extreme weather events. The 9th district, in this case, was established on a mostly hydromorphic site due to the various years of drought that the country has experienced. Therefore, the hydromorphic and floodable soils, where flood recession sorghum and market garden crops were produced, were sold to the population by the Boulama (chief of village) because of increased demographic pressure in the city center and rapid urban expansion. But in recent years, the situation of people living in the flood depressions around N'Djamena has changed. Some seasons have seen heavy rainfall, leading to disastrous flooding.

The inhabitants of the 9th district are victims of recurrent flooding. In 2012, the government and the mayor's office were forced to relocate the inhabitants from the flood plains (Ngoumna) to the emerged plains (Toukra). In 2020 and 2022, all the quarters of the district were affected by flood waters and houses collapsed, causing several casualties. Thus, climate variability is both a cause of human settlement in marginal areas, due to successive dry years, and of the destruction of buildings, due to recurrent flooding. What role does the climate really play in the settlement of the marginal areas of N'Djamena? What is the future of these areas, knowing that climate variability is an inevitable phenomenon? What measures are being taken to protect these areas? These questions will guide this article, which aims to demonstrate the role of climate in the sprawl of the city of N'Djamena on the *non aedificandi* zones.

II. MATERIALS AND METHOD

This study is based on the results of our field surveys as part of a scientific research for a PhD degree. This district is located between 12° 0' 44" and 12° 6' 30" North latitude and 15° 1' 59" and 15° 9' 47" East longitude. The reading of previous works and the exploitation of rainfall data of the city of N'Djamena from 1950 to 2018 have allowed to understand the problem and to know the fluctuation of rainfall. Studies on the growth of the city of N'Djamena and reports from various national and international NGOs on the state of flooding in the city of N'Djamena in 2012 and 2022 were very important. These data are complemented by field observations between 2019 and 2022 in the flood-affected neighborhoods in the 9th district of the city of N'Djamena. Interviews with disaster victims and leaders on the field were crucial to the production of this document. The demographic formula $P_n = P_0 (1+r)^n$ allowed us to project the population of the 9th district.

III. RESULTS

➤ Rapid Population Growth in the City of N'Djamena and its Impact on the 9th District

The strong increase in population and the concentration of the central districts of the city of N'Djamena have led to its extension by the multiplication of peripheral districts. N'Djamena alone represents 39.6% of the country's urban population [15]. The absence of official land building production has led to an anarchic occupation of the peripheral areas. This has increased its surface area as the number of the inhabitant increases.

The population of the city has increased from 530,965 in 1993 to 993,492 in 2009 [16]. Today, the population is estimated to be over 2 million with a growth rate of 4% per year. At the same time, the growth of urbanized areas has become spectacular. During the periods 1993 and 2009, the area occupied by the city increased from 6,227 ha in 1993 to 21,389 ha in 2009 [17]. Under the pressure of the need for building land, the city spanned the Chari River.

The population of the 9th arrondissement, a direct consequence of the expansion of the Chadian capital, has also increased. Due to the restructuring of the city center, 12,000 people were relocated to the district. They were effectively rehoused in 2011. The following figure 1 illustrates the population growth situation in the district.

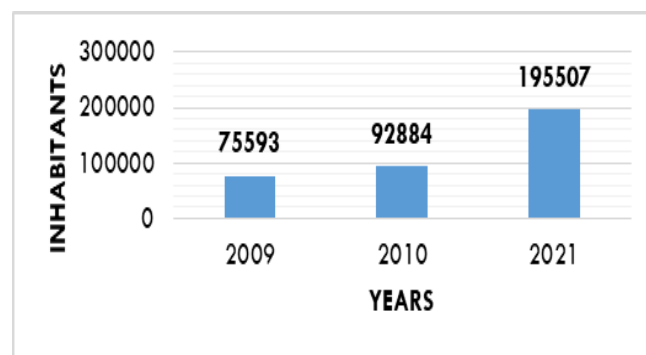


Fig 1 Population Growth in the 9th Arrondissement
Source: Gassina P., September 2020

Figure 1 shows that the population of the district has grown from 75,593 inhabitants in 2009 to 195,507 inhabitants in 2021. In 2010, it received 12,000 inhabitants from the city center. A new quartier was created for these inhabitants, namely Gardolé Djedid, which in local Arabic means new Gardolé. Thus, from 75,593 in 2009 to 92,884 in 2010 thanks to these inhabitants.

➤ Rapid Expansion and Anarchic Occupation of Spaces in the 9th District

From 1990 to 2008, the land between the Chari and Logone rivers continued to be the scene of accelerated occupation by the populations in a traditional and illegal manner under modern law. In 2008, the city authorities decided to make the entire 15 km of inhabited areas between the Chari and Logone rivers into a district, despite the restriction of urbanization on the left bank of the Chari by the Reference Urbanization Plan of the city of N'Djamena

[18]. This occupation continued until 2020 to include the villages of Sokolo, Daza, and part of Malo (formerly villages of the sub-prefecture of Koundoul after the creation of the district).

The extension of the district has been achieved through the construction of spontaneous settlements which reveal the

absence of state constraints and any logic and rules of urban planning [19]. The depressions are occupied, and the types of habitats are often not adapted to the soil conditions. Most of these depressions are flooded during the rainy season. Figure 2 shows the general land use situation from 2008 to 2020.

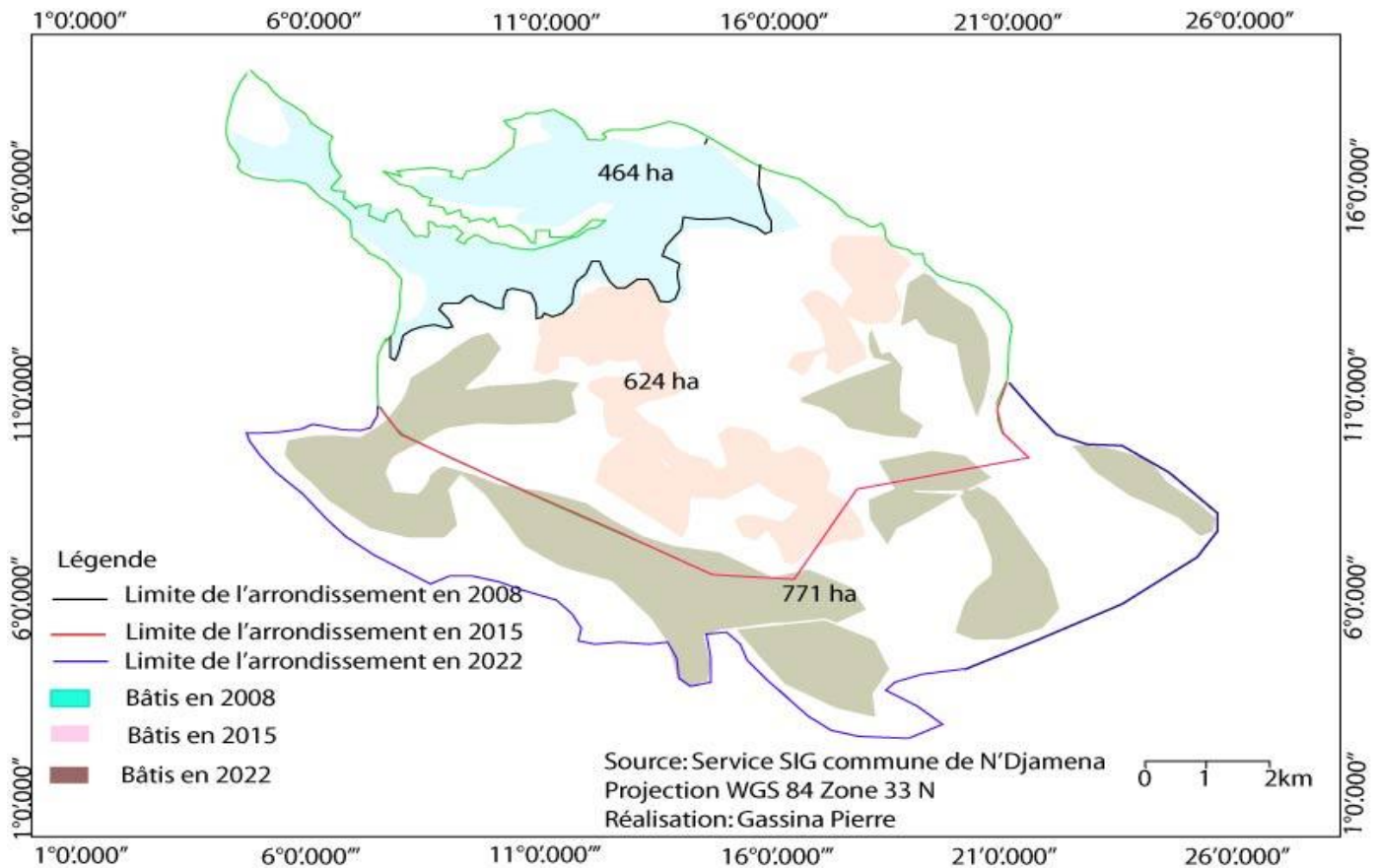


Fig 2 Extension of the 9th District from 2008 to 2020

Figure 2 shows that in 2009, the area of the district was 464 ha and reached 624 ha in 2015 [20]. In 2020, it has reached 761 ha, i.e., an increase of 297 ha in 11 years or 27 ha per year.

➤ *Anarchic Settlement in Peripheral Areas*

In the various quarters of the 9th district, the land acquired and inhabited depends on the developer who allocates or sells the land. Normally, the land registry (LR) and the Urban Land Allocation Commission (ULAC) are the only bodies responsible for the subdivision, allocation, and sale of building land in the country. Unfortunately, many inhabited plots of land in the 9th district often lack land titles because they were acquired in the traditional way. The population has been able to settle without effective control of the space by the state [21]. Figure 3, based on field data, classifies the types of land according to their acquisition status.

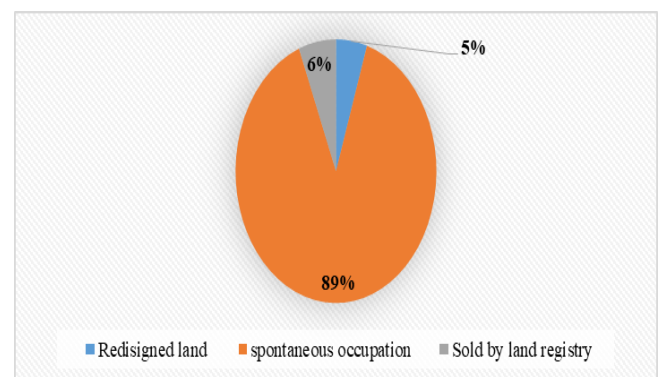


Fig 3 Status of Land at the Time of Acquisition
Source: Gassina P., September 2020

Figure 3 shows the status of land at the time of acquisition in the 9th district. 91% of the inhabitants of the district acquired their land before the restructuring, i.e., in the traditional way from the natives, 5% obtained their land at the time of the restructuring or afterwards, and 4% bought land already parceled out by the public authority or its partner, Land and Real Estate Development Company (LREDC).

➤ *Rainfall Deficits Favoring the Installation of Housing in Depressions*

Located in the Sahelian area of the country, the city of N'Djamena is part of a very dry climate, with often very low and irregular rainfall and high temperatures [22]. Successive deficit years are numerous in the Chadian Sahel as in the other climatic zones of the country. The following figure 4 shows the rainfall for the decade 1980-1990.



Fig 4 The Rainfall of N'Djamena from 1980 to 1990
Source: Gassina P., September 2020

The figure 4 shows that the rainfall varies between 226 and 631 mm. The average is 425.5mm, which is below normal [23]. These deficit years constitute the "dry period" which favored the occupation of the marshy areas between the Chari and Logone rivers, called *non aedificandi* lands.

Houses have been built on flood plains and even in drainage ditches, altering the course of run-off water which can only end up in public roads and buildings, causing

inconvenience to many families [24]. Some houses are surrounded by rice fields, which are cultivated by the inhabitants because of enough water in some wet years. Photo 1 illustrates the situation.



Picture 1 Occupation of *Non Aedificandi* land by the Inhabitants

Source: Gassina P., September 2020

Picture 1 Shows Houses Surrounded by Rice, Cultivated by the Inhabitants Thanks to Enough Rainfall in 2020.

➤ *The Process of Returning to Normal Rainfall in the Sahelian Zone*

After the dry years, which allowed the occupation of the *non aedificandi* spaces of the depressions between the Chari and Logone rivers, the rainfall has recovered as shown in the following figure 5.

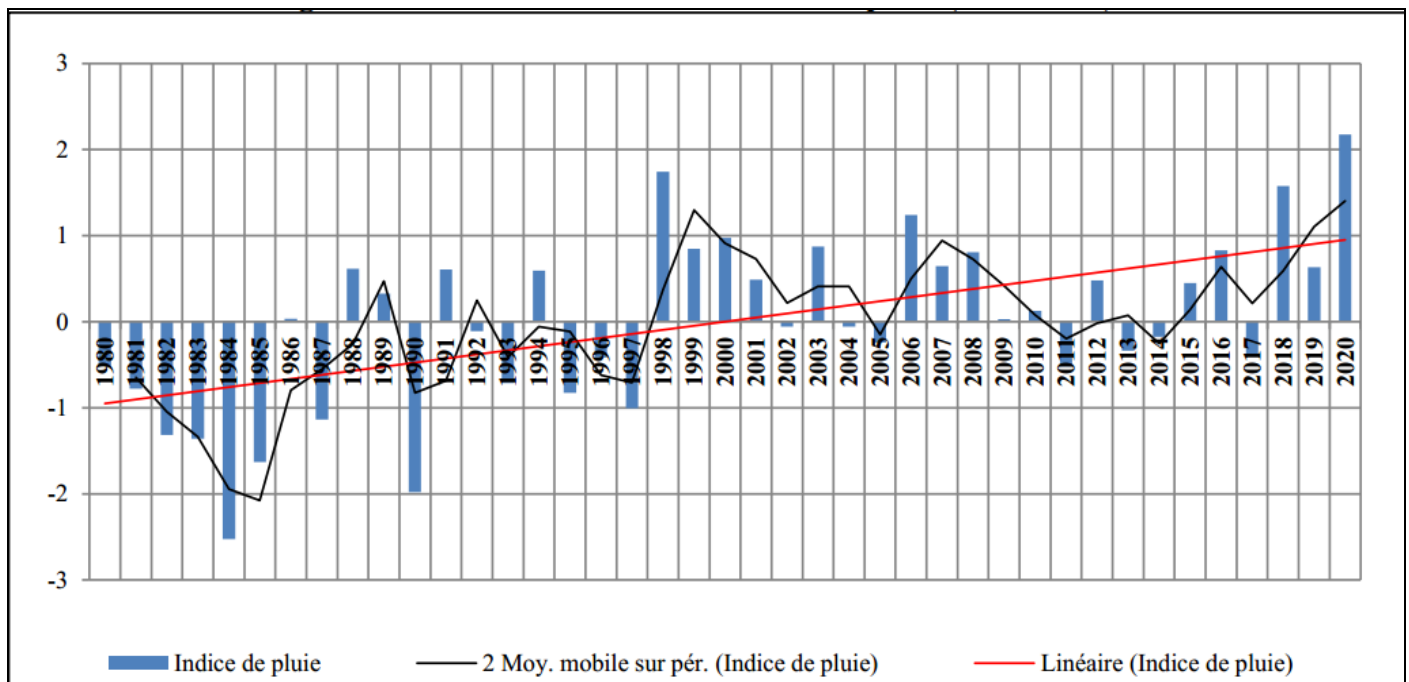


Fig 5 The Rainfall Evolution from 1980 to 2020
Source: Beauvilain (1995), ASECNA and ANAM (2021)

The figure 5 shows that during the period from 1980 to 2000, rainfall remains globally deficient except for the year 1998. The severe years are 1985, 1986 and 1991. These low extreme indices attest to the drought situation of this period [25]. However, the following decades, i.e., 2001-2010 and 2011-2020, are wetter than the 1980-2000 period (two decades). The indices are positive outside 2011, 2013, 2014 and 2017.

Between the deficit periods known as the decade of great droughts in the 1970s and 1980s, and the periods of return to normal, the urbanization of the city of N'Djamena has spanned the Chari. This urbanized area is now experiencing difficulties in terms of rainwater drainage and protection against river flooding.

➤ *Flooding Process and Damage to Dwellings*

The flooding process in the hydromorphic areas of the 9th district takes place in several stages. The relief of the district, like the rest of the city, is generally flat [26] and consists mainly of clay soils. At the beginning of the rainy season (May-June), the clays that make up most of the soils of the plain form an impermeable layer on the surface. In August (the wettest month), the soil becomes saturated. If rainwater is abundant, it runs off and fills the depressions. As these depressions are occupied by houses, the water first flows between unbuilt areas, including streets, vacant lots and drainage ditches dug by the inhabitants. As rainfall intensifies and the soil becomes saturated, water invades homes and houses built with unsustainable materials collapse. The yards of those built with durable materials are flooded and resist the water. The following pictures illustrate the situation.



Picture 2 Flooded Permanent Houses
Source: Gassina P., September 2020



Picture 3 Maisons Collapsed Non-Durable Houses
Source: Gassina P., September 2020

Image 2 shows dwellings made of hard materials that are resistant to flooding and image 3 shows, in contrast, dwellings made of non-durable materials that have collapsed.

In years with very high rainfall, flooding occurs when river water spills over the banks of the Chari and Logone. The water flows through the inter-levy corridors or natural drainage channels of the plains and tributary basins. Rainwater and river water are therefore interconnected. The flooded areas are therefore a function of the fluvial inputs and the rainfall.

➤ *Exceptional Rainfall in 2022 and Flood Disasters in the 9th District*

In 2022, the rainy season was exceptional. From the end of September, the usual beds of the two rivers were filled and gradually overflowed in specific places: the Ngonba outlet for the Chari and the Kabé outlet for the Logone. The water level of the Chari at N'Djamena was exceptional during this year's rainy season. This is because it remained higher than in previous years following the 1960s. The following figure shows the level of the Chari

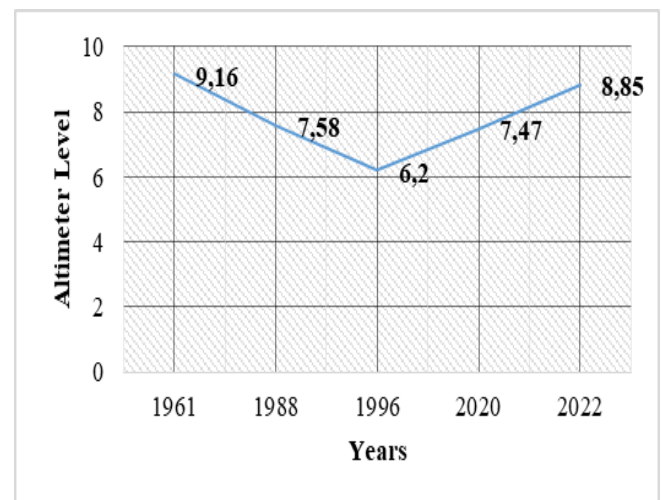


Fig 6 Evolution of Altimeter Level of Chari
Source: Water Resources and Meteorology Department (2022)

The figure above shows a curve of the evolution of the maximum level of the Chari between 1961 and 2022. In 1961, the level was 9.16 m, which corresponds to the wet period of the Sahelian climate. This curve reached its lowest point in 1996 when its numerical value was 6.20 m. This corresponds to the driest period in the Sahel. But in 2020 and

2022, the water level of the Chari has risen by 7.47 m and 8.85 m respectively. This is the period of improved rainy seasons in the area where flooding is recurrent.

The following map shows the situation of the flooded areas of the city of N'Djamena in August 2022.

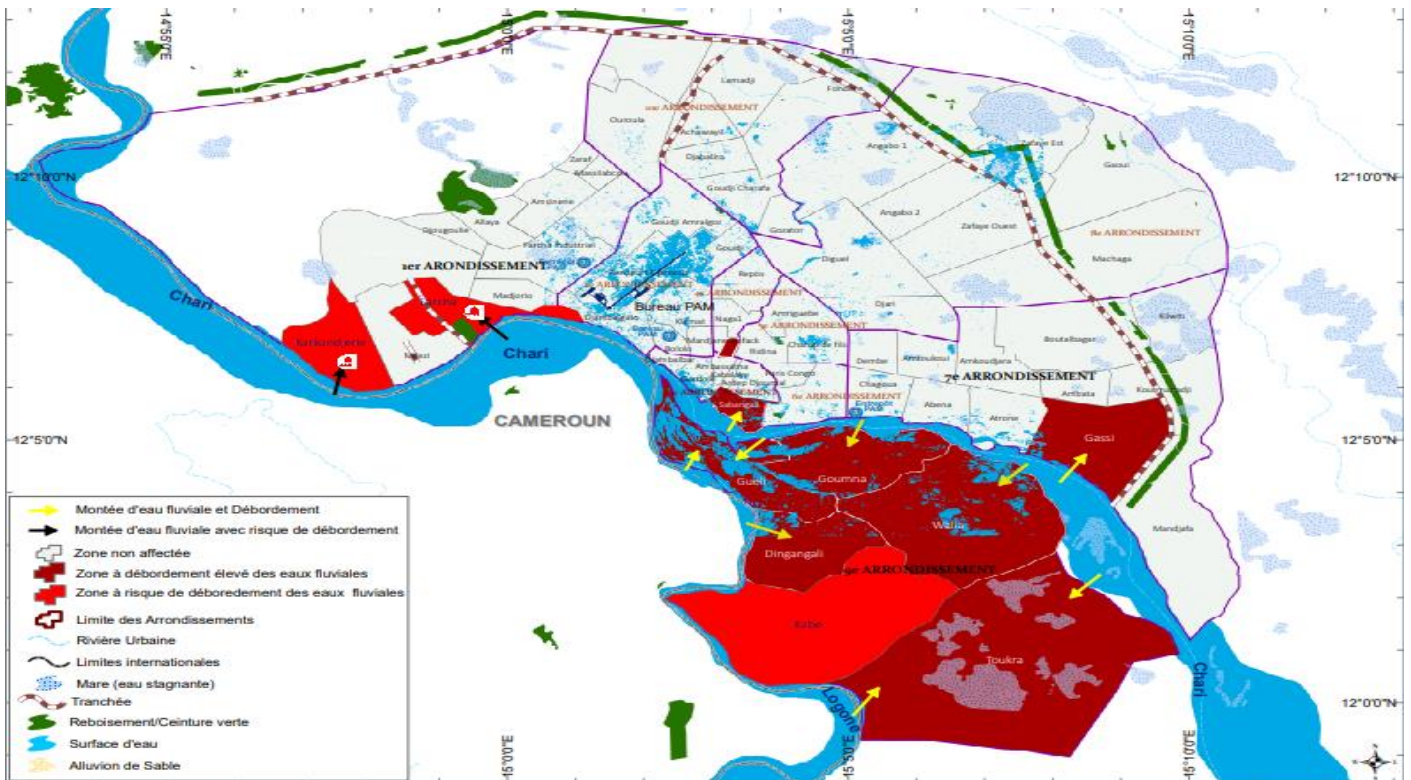


Fig 7 Flooded Zones in N'Djamena in 2022
Source: WFP and IOM, 2022

The map above shows in red the depressions flooded between September and November 2022. Thus, the entire area between the two rivers (Logone and Chari), i.e., the 9th arrondissement, is affected by rainwater and river water.

The victims are accommodated in the Walia, Toukra and Nguéli bulges.

➤ *Fighting Floods in the 9th Arrondissement*

The inhabitants of the 9th arrondissement are often confronted with floods each time this event occurs. The fight against these plagues is limited to the erection of dikes around the concessions to protect them from the rising waters.



Picture 4 Embankment quarries
Source: Gassina P., September 2020



Picture 5 Erection of Embankments Around Housing
Source: Gassina P., September 2020

Image 4 shows a fill quarry used by residents threatened by flooding and image 5 shows the placement of fill bags to protect homes from flood waters

To control the river's waters, the government has demarcated the areas at risk and built a dike around the houses to protect them from flooding. It winds through the district, separating it from the Chari River to the north and the marshy areas to the west.



Picture 6 Dike Protecting the District from River Water
Source: Gassina P., September 2020

Image 6 shows the dike built by the government to isolate the habitats from flood waters.

To channel water to natural reservoirs or to rivers and their tributaries, canals are built and maintained by the populations. These canals are often obstructed in the dry

season by various types of waste. Many of these canals often do not lead to a river outlet. They allow the inhabitants who have built their houses in non-durable materials to resist rainwater. They also facilitate the circulation of city dwellers between blocks and squares during the rainy season.



Picture 7 Rainwater drainage channel
Source: Gassina P., August 2020

Picture 7 shows the canal dug by the inhabitants of Ngonba to evacuate flood waters in 2020.

To combat recurrent flooding due to rainwater in the Ngoumna neighborhood, the mayor's office has built a natural rainwater retention basin. Indeed, during the 2012 floods that led the government to relocate the affected inhabitants of the Ngoumna neighborhood to the Toukra neighborhood, the rainwater retention basin was built. This basin, with a capacity of about 5,000 m², has solved the problems of circulation in the rainy season for the inhabitants of the center of the district. The neighboring houses are no longer flooded because the rainwater is all drained into this basin.



Picture 8 Ngoumna rainwater retention basin
Source: Gassina P., September 2021

Picture 8 shows the water retention basin in the Ngoumna neighborhood. It is installed on the depression that housed the inhabitants who were evicted by the Government during the 2012 floods.

IV. DISCUSSION

The city of N'Djamena has experienced rapid population growth and accelerated expansion resulting in the creation of peripheral districts, including the 9th and 10th districts in 2008. Inhabitants settled on marginal lands without adequate urbanization plans. These results confirm the work of Kossoumna in the city of Yagoua where population growth has led to the absence of adequate urbanization plans; the populations, dictated by their extreme poverty and uncivil behavior, are settling in an anarchic manner.

The city has expanded anarchically towards certain marginal zones despite the restriction of the Reference Urbanization Plan of the city. Martin Luther and Ngaressem agree with us that the absence of state constraint and all the logic and rules of urban planning leads to the construction of spontaneous housing and makes the cities expand. Our results show that 89% of the land is occupied spontaneously. Ngaressem admits this because he argues that the population of N'Djamena's peripheral neighborhoods has been able to settle without effective control of the space by the State.

This expansion onto the hydromorphic land of the 9th district was favored by poor rainfall during the period from 1980 to 1990. This is demonstrated by Gassina, as he notes that the deficit years favored the occupation of the marshy areas between the Chari and Logone rivers. Ramadan adds that houses are built on flood plains and even in drainage ditches that have led to the modification of the course of runoff water.

In recent years, rainfall has improved in the Sahelian zones. An increase in rainfall leads to flooding in inhabited depressions. Gouatene noted, overall, that the decades 2001-2010 and 2011-2020 are wetter compared to previous periods, except for the 1960s. The latter periods, he added, have resulted in recurrent flooding in the 9th Ward, especially in 2012, 2020 and 2022.

The flooding process proceeds in stages. First, there is flooding of the clay soils, followed by water flowing between unbuilt areas, including streets, vacant lots, and swales. This was noted by Madjigoto who adds that with the intensification of rainfall and saturation of the soil, water invades the houses. After that, the flood waters of Logone and Chari take over to increase the damage.

In 2022, the rains were exceptional. They led to an increase in the altimetric level of the waters of the Chari. This caused exceptional flooding in the 9th district where all the neighborhoods were affected.

In addition to the migration of inhabitants to reception centers such as schools and public reserves of flooded land, the inhabitants are fighting against the floods. They set up dikes and gullies to protect themselves from floods and drain the flood waters. The town hall has also built a dike around the district to protect it from the flooding of the Chari and Logone rivers.

V. CONCLUSION

Urban growth in tropical Africa is spectacular and often creates cities whose extensions cannot be controlled by the public authorities. When it occurs, it exposes many inhabitants to extreme meteorological phenomena, particularly flooding in *non aedificandi* areas. The main factor indexed is the uncontrolled settlement of populations in risk areas [7] due to the unavailability of building land and climate change. This exposes both the natural environment and the populations living there to a certain precariousness. The public policies put in place to remedy the situation consist in restructuring the anarchic lands, the erection of dikes to protect against floods and the emergency intervention to relocate disaster victims in case of flood.. The recommendations suggest the production of land for construction, control of facilities in the urban perimeter, improvement of the dike and stormwater drainage networks.

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