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## **Analysis of Vulnerability and Adaptation Strategies to Climate Change at the Scale of Neighbourhoods in the Agglomeration of Pointe-Noire (Republic of Congo)**

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### **Abstract**

Located in the coastal plain, the agglomeration of Pointe-Noire, the economic capital of the Republic of Congo, is highly exposed to the effects of global climate change and urbanisation. The objective of this article is to analyse vulnerability and resilience at the neighbourhood level in the agglomeration of Pointe-Noire. Data from surveys conducted in the neighbourhoods of Kilomètre 4 in the city centre, Ngouaboussi and Tchiali in the periphery were analysed using Phynx software. The main results show that

the climate of Pointe-Noire is marked by a very recent recession in rainfall totals and a decrease in rainy days. This climatic environment generates numerous extreme phenomena, the most cited being flooding, erosion and silting. They are aggravated by accelerated and uncontrolled urbanisation, poorly thought-out development and bad land management policies. Several strategies have been put in place by individual populations to adapt. Unfortunately, they remain ineffective and ephemeral.

**Keywords:** Pointe-Noire, Neighbourhood, Climate Change, Vulnerability, Resilience

### **1. Introduction**

Pointe-Noire is located in a coastal area. This geographical position makes it a town that is highly exposed to the effects of both global climate change and urbanisation (Ennesser Egis *et al*, 2016) <sup>[1]</sup>. Indeed, the melting of continental glaciers and the thermal expansion of the oceans, resulting from rising temperatures, are causing sea and ocean levels to rise year on year. According to IPCC (2018) <sup>[2]</sup>, the rate of sea level rise is estimated to have been 1.8 [1.3-2.3] mm/year on average between 1961 and 2003 and about 3.1 [2.4-3.8] mm/year on average between 1993 and 2003. Sea level rise accelerates and exacerbates coastal erosion in many overcrowded coastal cities (GIEC, 2014; Marion Mellol, 2014; Ozer, Hountondji & De Longueville, 2017, UNESCO/IOC, 2012) <sup>[3, 4, 5, 6]</sup>. The losses caused are very large and the repairs very costly. Unfortunately, the potential for adaptation is very limited or even poor in these cities.

To this permanent aggression from the ocean, we should add the effects of urbanisation, which weakens the urban site of the Pointe-Noire agglomeration. The presence of socio-economic infrastructures makes this locality a very attractive city. There has been an accelerated growth in the population, which rose from 7537 inhabitants in 1990 to 715334 in 2007. In 2015, the city reached the milestone of 782145 inhabitants in 2015 (Koua Oba, 2020) <sup>[7]</sup>. Currently, the population of the Pointe-Noire agglomeration is estimated at more than 1.1 million inhabitants. This demographic explosion has resulted in a regular and significant spread of the urbanised area. Available data show that the urban fabric of the Pointe-Noire conurbation has grown from 5,500 ha in 1974 to almost 14,800 ha in 2014, i.e. 300 ha per year (Ministère de la Construction, de l'Urbanisme, de la Ville et du Cadre de Vie, 2016) <sup>[8]</sup>. In thirty years, the surface area has practically tripled. We are witnessing anarchic occupation of space, the birth of new districts and new neighbourhoods. These neighbourhoods often lack adequate structures to ensure a better living environment for the population (Ministère de la Construction, de l'Urbanisme, de la Ville et du Cadre de Vie, 2016) <sup>[8]</sup>. We can cite the inadequacy and limitations of communal infrastructures, deficiencies in domestic wastewater systems, deficiencies in the rainwater drainage system, and the inadequacy and limitations of solid waste systems (Faye, 2014) <sup>[9]</sup>. These are 'precarious neighbourhoods', also known as 'African towns', which are overcrowded and inhabited by poor people: the case of Tchiali and Ngouaboussi in the Mongho-Mpoukou district. They are opposed to the neighbourhoods of rich men formerly occupied by the colonists, commonly called the 'European city', which are more or less equipped with social and health infrastructures. This is the case of the Kilomètre 4 neighbourhood in the Lumumba district. These disparities can mean that the effects of climate change are not felt in the same way by the populations living in the same city and that the degree of vulnerability and level of resilience are different from one district or neighbourhood to another.

Uncontrolled occupation is at the origin of the degradation of the living environment, especially in the precarious neighbourhoods. Numerous phenomena have been reported in previous studies: continental erosion, silting and flooding (Sitou & *et al*, 2022; Ngatsé, 2021)<sup>[10, 11]</sup>.

This study raises a number of questions:

- What is the endogenous perception of climate change in the neighbourhoods of Pointe-Noire?
- What are the climate-related problems in the neighbourhoods?
- What are the local adaptation strategies implemented by the populations?

These are the questions around which the present study will focus, the objective of which is to assess the degree of vulnerability and the level of resilience of the peripheral and central districts of Pointe-Noire to climatic hazards.

## 2. Materials and Methods

### 2.1 Study Area

The city of Pointe-Noire is located in the south-eastern part of Congo (Fig 1). Located between latitudes 4° and 5° south and longitudes 11°30" and 12° east, Pointe-Noire is influenced by a humid tropical climate. It is characterised by an alteration of seasons: rainy season (October-November-December and March-April-May) and dry season (June-July-August-September). Pointe-Noire has 6 districts which are: Lumumba, Mvoumvou, Tié-Tié, Loandjili, Mongo Mpoukou and Ngoyo.

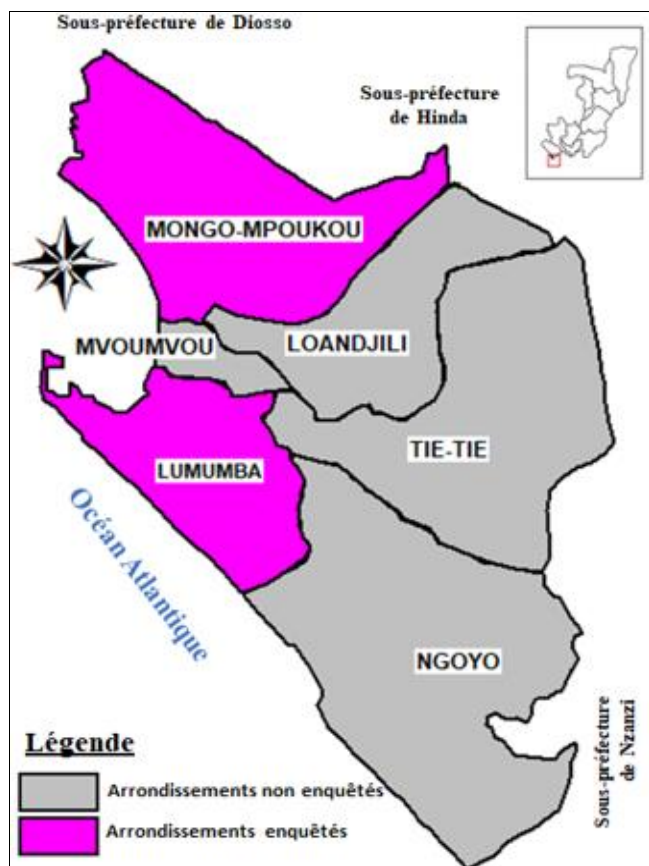


Fig 1: Agglomeration of Pointe-Noire

## 2.2 Materials

### 2.2.1 Literature Search

It consisted of the exploitation of documents relating to the city of Pointe-Noire on the one hand, and those dealing with issues related to the vulnerability and resilience of cities in the Congo and in Africa south of the Sahara on the other. These documents were consulted both online and in documentation centres and libraries.

### 2.2.2 Field Data Collection

The field research was carried out in neighbourhoods located in two distinct districts. These were the Lumumba district, which is the city centre, and Mongo-Mpoukou, a new district located in the peripheral zone. In the Lumumba district, the surveys were conducted in the Kilomètre 4 neighbourhood, and in Mongo-Mpoukou, we surveyed the Tchiali and Ngouaboussi neighbourhoods. We used two techniques to collect data: exploratory walks and direct interviews.

**Exploratory walks:** After the interviews with the authorities in each district, based on an interview guide, we visited the problem sites they indicated to us.

**Direct interviews:** After exploring the areas in degradation, the second phase consisted of direct interviews. They concerned only the populations of the neighbourhoods of Kilomètre 4, Tchiali and Ngouaboussi, living in the problem sites indicated by the neighbourhood leaders. In total, we surveyed 300 households, with 100 households per neighbourhood. The ideal of this choice is to see whether the problems are the same in the new (Tchiali and Ngouaboussi) as in the old (Kilomètre 4) neighbourhoods of Pointe-Noire and how the people react. In other words, it was a question of collecting information, based on a questionnaire, on the populations' endogenous knowledge of climate change and variability. In fact, the information sought concerned

- The perception of the inhabitants on the evolution of precipitation;
- The problems that plague these neighbourhoods in relation to the observed rainfall fluctuations;
- And the local adaptation strategies put in place and their results.

### 2.2.3 Data Processing Methods

After collection, the data was entered and statistically processed using Sphynx software. Excel was also used to produce graphs and statistical tables.

## 3. Results

### 3.1 Characteristics of the Surveyed Populations

#### 3.1.1 Age Distribution

The interviews conducted in the three neighbourhoods involved almost all age groups.

However, the most interviewed people ranged from 21 to over 60 years of age in the different neighbourhoods (Table 1). This has the advantage of dealing with people who are able to grasp certain realities of their respective neighbourhoods. Age has an influence on opinions. The older you are, the clearer your knowledge of the development of the neighbourhood and the climate.

**Table 1:** Age distribution of respondents

Neighbourhoods	Age groups							Total
	No answer	Under 20 years old	21 to 30 years old	31 to 40 years old	From 41 to 50 years	From 51 to 60 years	Over 60 years	
Tchiali	3	2	24	26	21	8	16	100
Kilometre 4	3	3	18	30	15	14	17	100
Ngouaboussi	1	2	13	11	21	26	26	100
Total	7	7	55	67	57	48	59	300

**Data Source:** Survey from 5 May to 30 June 2022

**3.1.2 Distribution by Gender**

The field investigations also took into account the gender aspect, i.e. they covered both men and women, all age groups combined (Table 2). This mix of information from men and women is very important for a good understanding of the realities experienced by the populations of each district. In Kilomètre 4 (41%) and Ngouaboussi (62%), men were more willing to answer the questions than women. In Tchiali, on the other hand, the percentage of women interviewed (57%) was higher than that of men.

**Table 2:** Gender distribution of respondents

Neighbourhoods	No answer	Male	Female	Total
Tchiali	2	41	57	100
Kilometre 4	0	65	35	100
Ngouaboussi	0	62	38	100
Total	2	168	130	300

**Data Source:** Survey from 5 May to 30 June 2022

**3.1.3 Level of education**

The respondents can read and write. Their level of education ranges from secondary to higher education (Table 3). 205 of the 300 people surveyed had a level of education ranging from primary to high school. Lower secondary education (collège) is the dominant level of education for people living in these three neighbourhoods (174 people).

The level of education is an important indicator for the appreciation of natural phenomena. Indeed, a schoolboy does not necessarily have the same degree of appreciation and understanding of the facts as an academic. The level of education can also help in the choice of housing areas. An

educated person can only move to risk areas if he or she has the means to do so.

**Table 3:** Educational level of the respondents

Neighbourhoods	Level						Total
	No answers	Not in school	Primary	College	High School	University	
Tchiali	13	2	11	33	21	20	100
Kilometre 4	20	0	14	30	21	15	100
Ngouaboussi	10	0	6	37	32	15	100
Total	43	2	31	100	74	50	300

**Data Source:** Survey from 5 May to 30 June 2022

**3.1.4 Duration of Settlement in the Neighbourhood**

In the various neighbourhoods surveyed, the native population is less represented (Table 4). The people surveyed had already lived in these neighbourhoods for between 10 and 40 years. A large number of natives were interviewed in Kilometre 4 (22%). It is easy to understand that this is an old neighbourhood, unlike Ngouaboussi and Tchiali. The latter two are inhabited by people from other districts. They are certainly attracted by the cost of rents or land deemed affordable by the lower strata of society. The longer a person stays in a neighbourhood, the more information he or she will have. The more time one spends in a neighbourhood, the better informed one is about the realities of the area. This means that an old and a new person in a housing area will not have the same knowledge of the facts and phenomena that undermine the area.

**Table 4:** Duration of settlement in the neighbourhood of the interviewees

Neighbourhoods	Age groups						Total
	No answers	Under 10 years	10 to 20 years	31 to 40 years old	over 40 years	Since birth	
Tchiali	5	26	51	13	2	3	100
Kilometre 4	8	13	27	20	10	22	100
Ngouaboussi	0	12	55	16	4	13	100
Total	13	51	133	49	16	38	300

**Data Source:** Survey from 5 May to 30 June 2022

**3.1.5 Status of Occupants**

The majority of the population in the three districts are plot owners, 67% in Tchiali, 64% in Kilometre 4 and 74% in Ngouaboussi (Table 5). However, there is a fairly large number of tenants in Tchiali (23%) and Kilometre 4 (26%). In Ngouaboussi, the percentage of tenants is very negligible (12%).

The status of the occupants can influence the decisions to be taken in the face of phenomena that undermine their neighbourhood. While a tenant will tend to move to another neighbourhood with fewer environmental problems, the owner is obliged to implement adaptation strategies to save his plot at any cost. He can only abandon it if the extent of the phenomenon makes his plot or the neighbourhood

unliveable. Erosion, for example, can make a neighbourhood uninhabitable. It can demolish houses or turn roads into ravines. As a result, the movement of people and cars becomes problematic. The consequence is that people will leave the area.

**Table 5:** Status of the inhabitants of the neighbourhoods surveyed

Status	Neighbourhood			Total
	Tchiali	Kilometre 4	Ngouaboussi	
No answer	10	10	14	34
Tenant	23	26	12	61
Owner	67	64	74	205
Total	100	100	100	300

**Data Source:** Survey from 5 May to 30 June 2022

### 3.2 Characteristics of the Neighbourhoods Surveyed

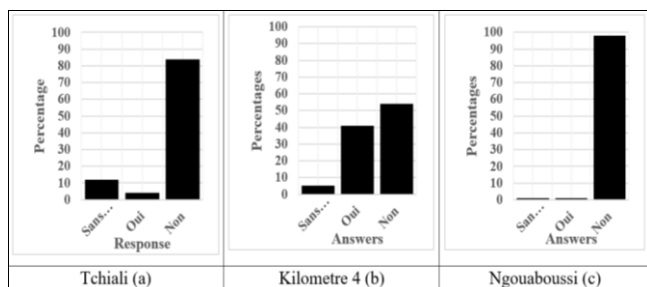
#### 3.2.1 River Network

The three districts surveyed are each drained by numerous rivers. Tchinouka, Tchikobo and Mafumu drain the Kilomètre 4 district, Ngoffo and Mouila the Tchiali district. As for Ngouaboussi, its hydrographic network is held by the Tchiloulou River and Lake Ngouaboussi. The presence of these rivers can cause flooding in these districts, for the plots located along these natural drains, especially if they are not maintained by the municipal services.

#### 3.2.2 Water and Waste Disposal

##### Rainwater and Wastewater Drainage

There is practically no rainwater or wastewater drainage system, especially in the districts of Mongo-Poukou. This opinion is shared by 84% of the people surveyed in Tchiali and 98% in Ngouaboussi. On the other hand, in Kilometre 4, 41% of respondents stated that there were gutters built for sanitation purposes. This network is very loose, not maintained and is open to the air (Fig 2).



Data Source: Survey from 5 March to 30 June 2022

Fig 2: Rainwater and wastewater drainage network

##### Disposal of Household Waste

The populations of Tchiali, Ngouaboussi and Kilomètre 4 use several means to dispose of household waste (Table 6). It is thrown into waterways, public dumps, gullies, drains or buried in the ground.

In Tchiali, 74% of the population dispose of household waste in natural collectors and 13% in gullies. In Ngouaboussi, the ravines are transformed into dumping grounds by the population (77%). In Kilometre 4, 51% of the residents dump household waste in natural collectors and 33% in public dumps. It is important to emphasise that the fact of transforming natural drains and the few gutters that exist into rubbish bins constitutes a danger for the populations living along these waterways and drains. As this waste clogs up the gutters and the minor bed of the rivers that water these neighbourhoods, even a normal rainfall event can cause flooding.

Table 6: Means of disposal of household waste

Answers	Neighbourhood		
	Tchiali	Kilometre 4	Ngouaboussi
No answer	2	5	0
Public dumps	6	33	2
Ravines	13	1	77
Burying in the ground	5	9	13
Natural collectors	74	51	2
Pipe	0	1	0
Total	100	100	100

Data Source: Survey from 5 May to 30 June 2022

All in all, it can be noted that the neighbourhoods we

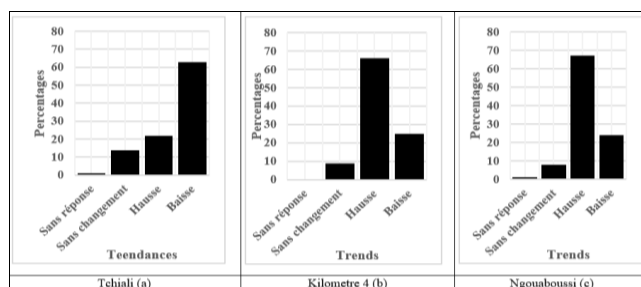
surveyed are well drained. These natural drains are used as dumping grounds for household waste, due to the lack of a provision put in place by the municipal authorities. There is a lack of a drainage network for rainwater and wastewater, especially in the neighbourhoods of Tchiali and Ngouaboussi. In these areas, there are more plot owners than tenants.

### 3.3 Endogenous Perception of Climate Variability

#### 3.3.1 Perception of the Evolution of Rainfall Totals

The opinions of the populations surveyed in Ngouaboussi and Kilomètre 4 on the evolution of rainfall totals converge. More than 60% of the respondents in these two districts noted that rainfall levels are clearly increasing, unlike the inhabitants of Tchiali. In Tchiali, more than 60% of respondents shared the opinion that rainfall totals were decreasing (Fig 3).

The decline and increase in the populations of these three neighbourhoods is recent. It dates back to less than 10 years ago. This opinion is shared by 65% of the inhabitants of Tchiali, 44% in Kilomètre 4 and 20% in Ngouaboussi.



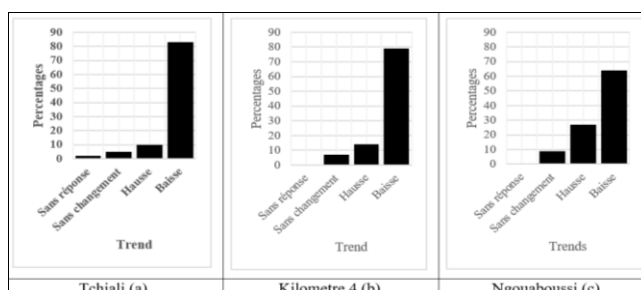
Data Source: Survey from 5 March to 30 June 2022

Fig 4: Evolution of rainfall totals

#### 3.3.2 Perception on the Evolution of the Number of Rainy Days

The respondents shared the same opinion on the evolution of the number of rainy days in the three districts. More than 60% of people in Ngouaboussi, Kilomètre 4 and Tchiali spoke of a downward trend in the number of rainy days (Fig 5). This decrease has been observed for less than ten years. This opinion is shared by 71% of respondents in Tchiali and Kilometre 4 and 62% in Ngouaboussi.

All in all, according to the opinions of the people surveyed in these three districts, the rainfall totals and the number of rainy days are evolving in opposite directions. While the rainy sequences are decreasing, the total amount of water is increasing. This implies that the rains that fall in Pointe-Noire in general and in these neighbourhoods in particular bring large quantities of water: this is therefore diluvian rain.

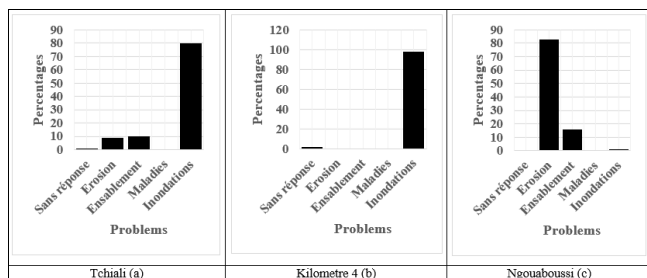


Data Source: Survey from 5 May to 30 June 2022

Fig 5: Evolution of the number of rainy days

### 3.5 Environmental Issues related to Rainfall Variability

The problems that plague the three districts are: erosion, silting, flooding and disease (Fig 6). However, the most recurrent problems are flooding in Tchiali (80%) and Kilometre 4 (98%) and erosion (82%) in Ngouaboussi. 53% of the inhabitants of Tchiali and 52% of those in Kilometre 4 say that the various problems in these two neighbourhoods are old. However, erosion and silting in Ngouaboussi are new phenomena in this district.



Data Source: Survey from 5 March to 30 June 2022

Fig 6: Extreme phenomena

#### 3.5.1 Event Zones

Each phenomenon has its preferred area. Flooding in Tchali and Kilometre 4 is most evident in the lowlands (Tchali: 83%; Kilometre 4: 55%) and in the major river beds (Tchali: 14% and Kilometre 4: 46%).

Erosion is recorded on the Ngouaboussi (98%) and Tchiali (4%) slopes. Silting is most noticeable in the lowlands of Tchiali and Ngouaboussi (table).

Table 6: Vulnerable Areas

Neighbourhoods	Vulnerable areas			
	No answers	Lowlands	Slopes	Riverbeds
Tchali	3	83	4	14
Kilometre 4	0	55	15	46
Ngouaboussi	0	98	42	11
Total	3	236	61	71

Data Source: Survey from 5 May to 30 June 2022

#### 3.5.2 Event Period

After the rain comes the good weather, so they say. But this is not the case in the three neighbourhoods surveyed. The rainy seasons are a source of misfortune for these districts. They bring flooding, erosion and silting. This view is shared by 100% of the respondents in Kilometre 4 and Ngouaboussi and 95% in Tchali (Table 7). During the dry season, people are at peace.

Table 7: Periods of occurrence of extreme events

Answers	Neighbourhood			Total
	Tchali	Kilometre 4	Ngouaboussi	
No answer	3	0	0	3
Dry season	0	0	0	0
Rainy season	95	100	100	295
At any time of the year	2	0	0	2
Total	100	100	100	300

Data Source: Survey from 5 May to 30 June 2022

#### 3.5.3 Causes and Coping Strategies

##### 3.5.3.1 Causes

Several causes are cited by the population to explain the phenomena that undermine the districts of Tchiali, Kilometre 4 and Ngouaboussi (Table 8). These are: climate

change, the lack of a rainwater and wastewater drainage network. When this network exists, it is too loose and often not connected, as the populations of Tchali (31%) and Ngouaboussi (54%) found. In fact, the natural collectors and the few rare pipes that exist are transformed into public dumping grounds. To these main causes, one must add the lack of dustbins (51% in Ngouaboussi) and the anarchic occupation of space (Ngouaboussi: 29% and Kilometre 4: 25%). The sale of plots by landowners and municipal authorities does not respect the cadastral plan of the city of Pointe-Noire. This creates a real problem of land management.

Table 8: Causes of vulnerability and aggravating factors

Answers	Neighbourhoods		
	Tchali	Kilometre 4	Ngouaboussi
No answer	2	0	1
Climate change	8	53	90
Lack of sewage system	65	64	82
Anarchic occupation of space	5	25	29
Lack of a waste bin	8	10	51
Loose sewage system	23	57	36
Lack of maintenance of pipes	31	54	17

Data Source: Survey from 5 May to 30 June 2022

##### 3.5.3.2 Local Adaptation Strategies and Suggestions

**Local Coping Strategies:** Several strategies are used by the inhabitants of the Kilometre4, Ngouaboussi and Tchiali neighbourhoods, depending on the most recurrent phenomenon and taking into account their income (Table 9). The most frequently cited strategies are:

- To protect themselves from erosion, people planted bamboo (36%) and grass (7%). They also pile up tyres and create embankments at the edges of the plots from bags filled with sand (23%);
- In order to fight against floods, people have developed curative and preventive measures.

Curative measures consist of evacuating water from the plot using containers (11%), or through a pipe dug with shovels. As preventive measures against flooding, people put a barrier at the door to prevent water from invading the house or fence off the plot to prevent water from coming in from outside.

Unfortunately, whether they are preventive or curative, these adaptation strategies do not produce the expected results. This opinion is shared by 81% of respondents in Tchiali, 75% in Kilometre 4 and 55% in Ngouaboussi.

Table 9: Adaptation strategies to climate change

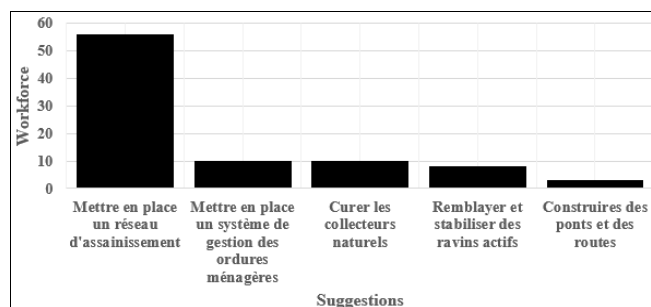
Strategies	Workforce
Planting of bamboo	36
Bags filled with sand	23
Individual pipe	14
Drainage of water through containers	11
Planting of grass/grass	7
Barricade the door with bricks	1
Fencing the plot	2
Stone walls	1
Overlapping of tyres	1

Data Source: Survey from 5 May to 30 June 2022

##### Suggestions

In order to make these three neighbourhoods resilient, several suggestions were made by the people surveyed (Fig 7). In order of importance, we can retain: the installation of

a rainwater and wastewater drainage network, the installation of a household waste management system, and the cleaning of gutters and natural drains. To these three suggestions, we can add the construction of roads and bridges and the stabilisation of ravines.



Data Source: Survey from 5 May to 30 June 2022

Fig 7: Suggestions made by respondents

#### 4. Discussion

African cities in general, and those of the Congo in particular, are by their very nature places where human crowds are concentrated. From year to year, the number of people living in cities is increasing. The socio-sanitary, educational and economic structures make cities very attractive environments. It is important to conduct studies on the problems that plague these cities. The aim of these studies is to identify the problems that concern them, to determine the causes and to put in place sustainable adaptation strategies. This is the only way to make cities resilient and preserve the lives of the people who live in them. It is in this context that the present study on the neighbourhoods of Pointe-Noire in relation to climate change was conducted. The investigations carried out in the neighbourhoods of Kilomètre 4, Tchiali and Ngouaboussi made it possible to identify several problems that undermine them, the most recurrent of which are flooding, erosion and silting. Flooding is recorded in all three districts. On the other hand, erosion is only reported in the peripheral districts (Tchiali and Ngouaboussi). These phenomena are both recent and new, depending on the neighbourhood. According to the inhabitants, these problems, which only appear in the rainy season, are closely linked to the climate. They are aggravated by anthropogenic causes. The strategies put in place by the populations to adapt are not adequate to deal with these problems, which are only getting worse as these neighbourhoods become denser and the climate changes. Faced with these common problems that degrade the living environment, the solutions are individual. Each inhabitant tries to adapt as much as he can according to his means.

The phenomena of erosion and silting in Pointe-Noire have also been highlighted in numerous works. To this end, we can cite the investigations conducted by Ngatsé (2021)<sup>[11]</sup>.

The results obtained showed that the manifestation of water erosion in Tchiali is the result of a combination of several factors: the lack of gutters, the construction of sewer 1, the destruction of the vegetation cover, the lack of maintenance of the gutters, the anarchic subdivision and the orientation of the road.

Many consequences result from this, such as the abandonment of neighbourhoods by their inhabitants, falling rent prices and difficulties in gaining access to the neighbourhood.

This view is shared by Sitou & al (2022)<sup>[10]</sup>. Indeed, following their work they came to the conclusion that the erosion observed in the districts of Pointe-Noire and specifically in Tchiali is the result of both natural factors (drained valley and sandy texture of the soils, fairly steep slopes and excess water) and anthropic factors (careless occupation of the site, poor management of rainwater (lack of gutters)).

The various studies carried out by our predecessors have ignored the major role played by the climate in triggering the problems that degrade the environment of the Pointe-Noire agglomeration. This is what makes our work original. These problems are also observed in many cities in Congo. In this respect, we can mention the agglomeration of Brazzaville. The work of Massouangui-Kifouala *et al* (2021)<sup>[12]</sup> showed that the precarious neighbourhoods of Soukissa and Moukondzi-Ngouaka, although old, are subject to flooding, erosion and silting.

In the absence of effective adaptation strategies, plots of land are abandoned or put up for sale, and houses are demolished or buried. Of course, the climate is partly to blame, but poor land management has also contributed significantly to the genesis of these extreme phenomena, which are decried by the population. The measures taken by the government in the framework of urban governance are not respected by landowners who sacrifice the balance of the environment and the living environment of the population to the detriment of their own pockets and profits. The passivity of the state is then put in the dock.

The literature review shows that Congolese cities are not the only ones affected by the impacts of climate change. Environmental problems are commonplace in neighbourhoods in many African cities. The aggravating factors are almost the same.

In Benin, the neighbourhoods of the coastal city of Cotonou, and more precisely the Enagnon neighbourhood, are threatened by the phenomenon of coastal erosion, which has become very recurrent over the last ten years (Sossou *et al.*, 2019)<sup>[13]</sup>. The populations of the Enagnon district located in the 4<sup>ème</sup> arrondissement of Cotonou have a good psychosocial representation of climatic extremes. Faced with these different situations, the inhabitants have developed a certain capacity for resilience in terms of habitat and anti-erosion measures. This involves the construction of collective terraces in the form of makeshift dykes and the planting of trees (Sossou *et al.*, 2019)<sup>[13]</sup>.

In the Union of Comoros, floods affect the three Comorian islands with an annual frequency of occurrence and a high probability of occurrence (Anwadhui, 2012)<sup>[14]</sup>. The factors that lead to the high vulnerability of the communities are mainly the lack of awareness and the non-application of an urbanisation guideline in high risk areas.

In Ouagadougou, it was found that the rainfall that causes flooding in the city of Ouagadougou is often normal. Their return period is less than 6 years. These floods are therefore the consequence of unplanned urban growth and not of changes in the frequency or intensity of extreme rainfall (Hangnon and *al.*, 2015)<sup>[15]</sup>.

In Algeria, the agglomeration of Sfax is prone to flooding. Despite the implementation of infrastructures in the centre of the city and its surroundings, flooding is gaining space over the years according to the extension of the agglomeration and its functioning. The new peripheral zones of Sfax intensify the runoff during rainy events because of

the impermeability of the soils. Moreover, several dwellings have occupied the wadi beds (Daoud and Dahech, 2012)<sup>[16]</sup>. In Mauritania, more specifically in the city of Nouakchott, flooding by rainwater has been observed in certain districts such as OCOGIM PS and in the municipality of Sebkh. This is linked to a combination of three main factors. These are the increase in rainfall totals observed at the beginning of the 1990s, the level of the water table and the absence of a wastewater evacuation system following poor urban planning and uncontrolled urbanisation. The massive arrival of populations following the rural exodus of the 1970s and 1980s led to the multiplication of constructions in flood-prone areas. The rainfall responsible for the current floods has, for the most part, a return period of less than 6 years. They are rarely exceptional or even abnormal (Niang, 2014)<sup>[17]</sup>.

In Cameroon, in October 2019, two consecutive extremely rainy days led to a landslide that demolished precarious hillside dwellings in the outskirts of the city of Bafoussam (Cameroon) and caused several casualties (Gnacadjia, 2020)<sup>[18]</sup>.

In Morocco, a record rainfall was recorded on 30 November 2010, which brought the equivalent of six months of rainfall in normal circumstances. The flooding caused by this rain has resulted in the closure of the international airport and many businesses as well as schools throughout the city. Many businesses lost their stocks of goods. More than 2,500 families have been displaced (Banque Mondiale, 2011)<sup>[19]</sup>. It is quite clear that when considering the risk of climate change, informal settlements are more vulnerable than others. First, the consequences of climate change disproportionately affect the poorest populations (UN-Habitat, 2011, Guivarch et Taconet, 2020)<sup>[20, 21]</sup>.

## 5. Conclusion

The objective of this study was to analyse the degree of vulnerability and the level of resilience at the neighbourhood level in Pointe-Noire to climate change.

Investigations carried out in the districts of Kilomètre 4 in the Lumumba district, Ngouaboussi and Tchiali in Mongo-Mpoukou have shown that the climate in Pointe-Noire is characterised by an increase in total rainfall and a decrease in the number of rainy days.

This climatic environment causes a number of problems, the most frequent of which are: flooding, erosion and silting. Flooding does not spare any district, whereas erosion and silting are the prerogative of the peripheral districts (Tchiali and Ngouaboussi). It seems clear that no neighbourhood is immune to the impacts of climate change, whether it is old or new. It is important to point out that certain extreme phenomena such as flooding have been occurring for a long time in the various neighbourhoods surveyed. However, as these neighbourhoods become more and more densely populated, they are becoming more and more worrying.

Environmental problems are aggravated by both anthropogenic and natural factors. Accelerated and uncontrolled urbanisation, poorly thought-out development and poor land management policies are the main aggravating factors cited.

In order to cope with this, several strategies are put in place individually by the inhabitants. Unfortunately, they are not very effective. In order to make the agglomeration of Pointe-Noire in general and the districts of Tchiali, Ngouaboussi and Kilomètre 4 resilient, it is important to

define a good urban governance policy. Particular emphasis must be placed on rainwater sanitation and land management.

In the future, it would be interesting to conduct a study on the future evolution of rainfall in Pointe-Noire. Knowledge of future trends in rainfall would make it possible to put in place sustainable adaptation strategies to make the Pointe-Noire agglomeration resilient to climate change.

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