**Edelweiss Applied Science and Technology**
*ISSN: 2576-8484*
*Vol. 9, No. 10, 306-323*
*2025*
*Publisher: Learning Gate*
*DOI: 10.55214/2576-8484.v9i10.10403*


# Urban vulnerability and adaptation strategies in secondary cities in Chad: Analysis of the case of the city of Pala

Sing-non Bourdannet Patouki[1,2*], Allarané Ndonaye[1,2], Nyiniwou Ismaila Kinyui[3], Djedanoum Romaric[4], Hetcheli Follygan[2]
[1]Regional Center of Excellence on Sustainable Cities in Africa (CERViDA-DOUNEDON), Lome 01 BP 1515, Togo; patouki.singnonbourdannet@cervida-togo.org , singb.patouki@gmail.com (S.B.P.).
[2]Research Laboratory on Spaces, Exchanges and Human Security, University of Lome, Lome 01 BP 1515, Togo.
[3]University of Yaoundé 1, Department of Geography, BP: 755 Yaoundé, Cameroon.
[4]University of Yaoundé 1, Department of Geography, Network of Excellence on Land Governance in Africa (REGFA), BP: 755 Yaoundé, Cameroon.

Abstract: This study assesses urban vulnerability from various angles in the city of Pala, Chad. To this end, we conducted a household survey of 340 residents in the city's 27 neighborhoods. The methodology used is based on a mixed approach that treats both qualitative and quantitative data. Thus, we targeted a number of indicators in the socio-economic field, exposure to risk and natural disasters, architecture, equipment provision, and finally, local adaptation capacities. The analyses showed that, in the absence of a drainage system in the city of Pala, 60% of respondents are vulnerable during the rainy season, compared to 40% who benefit from natural water runoff slopes. Simplistic analyses of satellite images of the waterways crossing the city show that any household located within a 60-meter radius of a waterway is vulnerable, given the city's high rainfall (where annual rainfall can reach 700 mm or more). Pearson's test (r=0.55) shows that climatic and environmental factors are also decisive. Economic vulnerability is characterized by the fact that more than 50% of this population lives on less than $1 per day. Architectural vulnerability is reflected in the precariousness of traditional building materials, which are exposed to various risks. The value of this research is not limited to understanding urban vulnerability in general, as it also sheds light on issues of resilience through local practices.

***Keywords:*** *Adaptation strategy, Pala, Secondary city, Urban vulnerability.*

## 1. Introduction

At the end of 2022, the world population exceeded eight billion [1]. This demographic increase is mainly concentrated in urban areas, which are constantly expanding and generate more than 80% of the global gross domestic product (GDP). By 2030, 60% of the world's population will live in urban areas. Due to rapid population growth, urbanization, and the development challenges posed by climate change, communities in sub-Saharan Africa are disproportionately vulnerable [2]. Between 2008 and 2018, more than 157 million people were directly or indirectly affected or vulnerable. Most of the hazards they face are hydro-meteorological [3]. The rapid pace of urbanization in Africa is well established. Within a generation, all African cities will have either doubled or tripled in population [4]. Urbanization on the African continent is largely unplanned and informal. For 50 years, urban development plans have been developed in sub-Saharan African cities without convincing results. One of the main explanations for this failure is the lack of basic data on cities and their inhabitants [5]. These cities and urban areas already concentrate a large part of the global challenges in terms of development, but also offer many opportunities [6].

Against a backdrop of rapid urban growth in Africa, secondary cities play a crucial role in structuring the territory and absorbing migration dynamics [2]. However, these cities, such as Pala in


**History:** Received: 6 August 2025; Revised: 15 September 2025; Accepted: 19 September 2025; Published: 8 October 2025
* Correspondence: patouki.singnonbourdannet@cervida-togo.org

Chad, face increased urban vulnerability linked to various natural and human factors. This situation exposes populations to major challenges, particularly in terms of access to drinking water, sanitation, transportation, and energy, thereby compromising their quality of life and resilience to climatic and socio-economic hazards. Faced with these shortcomings, residents are developing adaptation strategies based on informal mechanisms and community solidarity dynamics [7]. The objective of this study is to analyze the forms of urban vulnerability in Pala and examine the local responses put in place to compensate for the lack of facilities and services. The aim is to understand how these strategies influence urban functioning and to identify levers for action for more inclusive and sustainable planning. This complex issue requires an in-depth analysis of the adaptation strategies put in place by residents to address these challenges.

## 2. Literature Review

### *2.1. Urban Vulnerability*

Alongside hazard, the concept of vulnerability remains the weak point in the definition of risk [8]. It has been the subject of discussions and developments that have made it possible to take into account a number of social realities, but its place remains rather marginal [8]. It must be said that, faced with the evidence of hazards, particularly those of natural origin (earthquakes, volcanic eruptions, floods, landslides, etc.), supported by the certainties and tools of earth sciences, questions and developments in the concept of vulnerability generate a certain mistrust and incredulity, and mean that vulnerability does not stand up to the certainties of hazard [9]. Vulnerability appears to be a subject of the social sciences, by definition contingent and unclear, which everyone approaches in their own way to account for different things, but which all have to do with the intervention of the social in risk [10].

Urban vulnerability is a growing challenge in secondary cities in Central Africa, exacerbated by inadequate infrastructure that compromises the well-being of populations. Rapid urbanization, caught off guard by environmental and socioeconomic crises, creates fertile ground for vulnerability [11]. Vulnerability is defined as a city's reduced capacity to anticipate, cope with, and recover from environmental, social, and economic impacts [9]. Urban vulnerability refers to the susceptibility of cities to damage from various hazards, such as natural disasters, economic crises, or social conflicts [10]. It is exacerbated by factors such as high population density, poor urban planning, and socio-economic inequality, compromising the resilience of infrastructure and communities. In the scientific field, vulnerability is discussed in relation to all kinds of things, on all kinds of scales, and in relation to physical, material, and socio-technical elements as well as social or human elements [11]. But more often than not, what is expected of the social sciences in risk analysis is that they decipher the "vulnerability of the population," the "perceptions" or "representations" of risks by the population (in fact, often representations of hazards) and its "behavior" [2].

Understanding and mitigating this vulnerability is essential to ensuring sustainable development and safety in urban areas [12]. Urban vulnerability is not limited to large cities. Small towns and peri-urban areas can also be severely affected, especially when they experience rapid growth without adequate planning [13]. In addition, the poorest segments of the urban population are often those who suffer the most severe consequences due to their limited resources to protect themselves and recover from shocks [14].

Urban vulnerability in the context of architecture refers to the susceptibility of urban infrastructure to damage from various risks such as natural disasters, climate change, and socio-economic pressures. It results from the interaction between the physical characteristics of buildings, architectural design choices, urban density, and social, economic, and environmental dynamics [15]. Assessing this vulnerability involves identifying indicators related to design, location, and material quality, as well as the adaptive capacity of residents and institutions [16]. A low-income community living in a high-risk flood area will be more exposed due to its inability to relocate or improve local infrastructure [17]. It is essential to understand that these factors are often interconnected, which can further exacerbate vulnerability [18].

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

*2.2. Adaptation Strategies*

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) in 2014 was the most comprehensive to date. However, it left many gaps regarding the impacts, implications, and responses to climate change in Small Island Developing States (SIDS) [15].

Adaptation strategies are described as measures aimed at reducing vulnerability to environmental or climate change, often mentioned in documents from the Intergovernmental Panel on Climate Change (IPCC) and in literature on risk management and sustainable development. An adaptation strategy is a plan or set of actions aimed at reducing the vulnerability of a system, population, or organization to environmental, climatic, economic, or social changes or risks [19]. It involves adjusting practices, processes, or structures to better respond to the challenges and potential impacts of phenomena such as climate change, natural resource degradation, or other crises [2]. For example, in response to rising water levels, a city may adopt an adaptation strategy by building dikes or developing flood zones [20]. In agriculture, this could involve changing crops or using more efficient irrigation techniques to cope with drought [17].

The adaptation strategies implemented by the communities of Pala, such as strengthening local infrastructure and improving water management, demonstrate resilience in the face of crisis. As Satterthwaite [21] notes, the adaptive capacity of local communities is often key to their survival in adverse contexts. However, as Satterthwaite, et al. [22] suggest, these strategies must be fully supported by adequate public policies in order to be effective. By scrutinizing social, economic, and environmental realities, this research aims to develop an integrated understanding of the complexities of urban vulnerability in secondary cities in Central Africa and to offer informed recommendations for their future [7]. Therefore, the strategy for improving urban resilience must focus not only on improving physical infrastructure but also on community capacity building and social inclusion [23].

## 3. Materials and Methods

*3.1. Study Area*

The town of Pala is located in the southwestern part of the country, in the Mayo Kébbi-Ouest region, at 9°21'36" N; 14°52'20" E. A regional hub, the town of Pala is approximately 360 km from the capital N'Djamena and 140 km from the Cameroonian border, towards Figuil. It is crossed by the Figuil-Léré-Kélo-Moundou national road, which serves it. Administratively, the city of Pala is the capital of the Mayo Kébbi West region, the Mayo Dallah department, and the municipality of the same name. Established as a medium-sized municipality on June 21, 1961, under the name of Pala, the city has grown and now has 24 neighborhoods, structured into 117 blocks. According to this delimitation, the municipal territory of Pala covers an area of 192.7 km² or 19,270 ha. It is bordered to the north by the cantons of Gouin and Gouey-Goudoum, to the east by the cantons of Tagal and Gagal, to the south by the canton of Goumadji, and to the west by the canton of Doué. The 24 districts of the municipality of Pala are divided into four (4) boroughs. Map 1 below shows the administrative division of the study area.

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

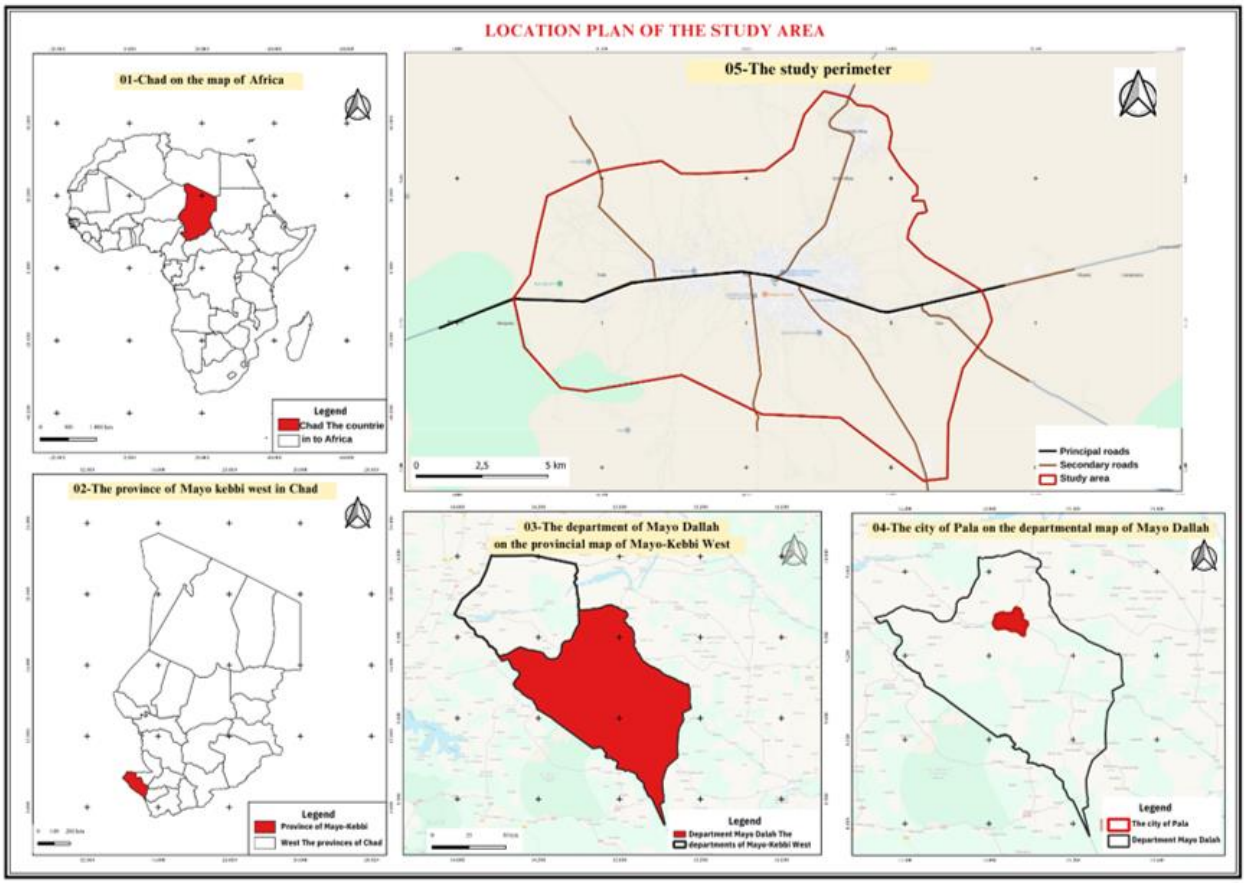


**Figure 1.**
Location of study area.

*3.2. Sampling and Data Used*

This study was conducted using a methodological approach based on documentary research, data collection on urban vulnerability, vulnerability risk mapping, group interviews with officials from public bodies responsible for urban management, and individual interviews with residents of the city's four districts. The documentary research enabled us to review similar work carried out in other geographical areas addressing the same issue. Data related to access to necessary urban services were obtained from the Urban Reference Plan (PUR), the Municipal Development Plan (PDC), study reports, and fieldwork. The use of urban vulnerability risk mapping, via sentinel data, allowed us to visualize the classification of vulnerability zones. For household interviews, we visited a number of households in each district, with the sample size proportional to the total number of households. Consultation of the town hall documents and archives revealed that the population of Pala is 47,982, comprising 11,389 households spread across the four districts. This population constitutes the target population for the survey. The distribution of households is as follows: the 1st district has 2,953 households, the 2nd district has 4,320 households, the 3rd district has 3,333 households, and the 4th district has 783 households. The Giorgi, et al. [23] adopted to determine the proportion of households to be surveyed by district is as follows:

$$N_q \geq \frac{4P\ (1\text{-}P)\rceil}{\sum a^2} \qquad (1)$$

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

Where n is the sample size, P is the proportion of the population with the characteristics sought, and a is the margin of error that we are willing to accept. This sample, taken from the four boroughs, comprises 340 households distributed as follows: 130 households in the 1st borough, 100 households in the 2nd borough, 70 households in the 3rd borough, and 40 households in the 4th borough. Households aged 19 and over are included in the survey. This age group was chosen because it is able to explain the issue of urban vulnerability over a decade during its period of residence in the study area. A reasoned choice was made to conduct surveys among the selected households. This approach was also used in a recent study conducted in Central Africa by Attipo, et al. [24]. The survey was based on a questionnaire with closed and open-ended questions. This method was used by Watson [25] and households were distributed according to population density in the 24 neighborhoods of the city of Pala.

*3.3. Research Methodology*

In order to carry out our studies, we adopted a methodology combining qualitative data, quantitative data, and data from satellite imagery. The qualitative method was used to gather users' perceptions and opinions on urban vulnerability over the last two decades. The quantitative method was used to calculate the various vulnerability factors in order to classify, compare, or standardize them using existing assessment grids or standards. The remote sensing and/or GIS approach was used to spatialize the vulnerability phenomenon to identify the most exposed areas and make projections. Figure 2 below shows the views of this methodology used.

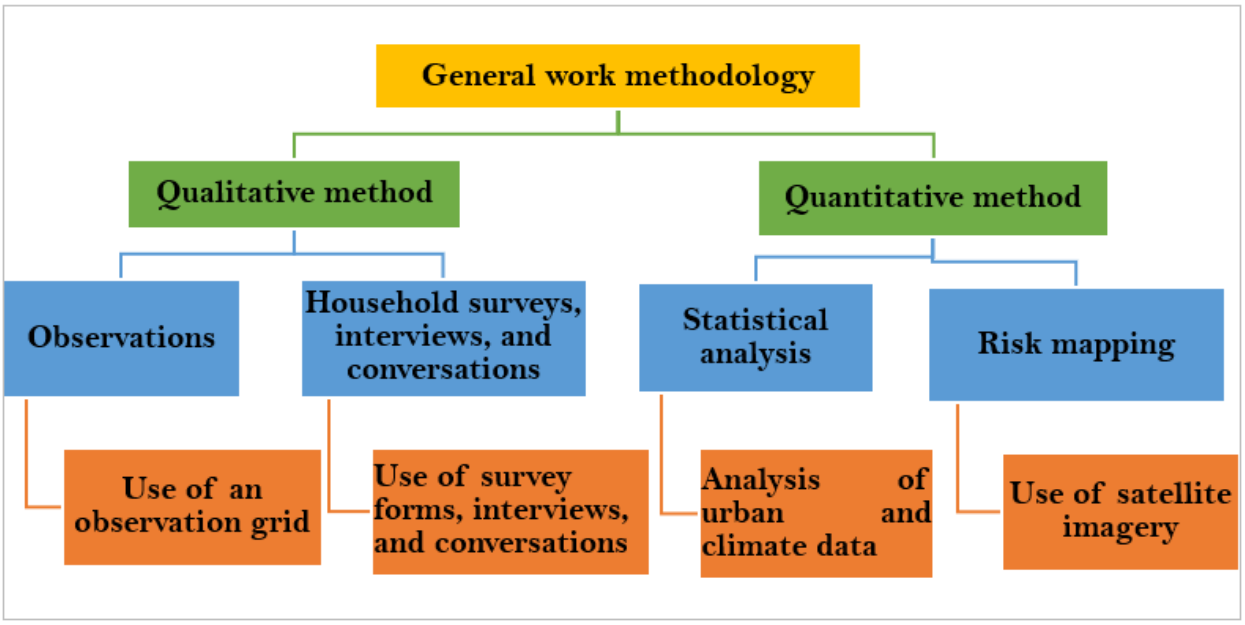


**Figure 2**.
Methodological diagram.

The methodology adopted involves gathering perceptions or opinions of the inhabitants of the city of Pala regarding the vulnerability they have been exposed to over the past 20 years. It is based on both qualitative and quantitative data. Remote sensing is employed to map areas with high exposure to various risks. For data processing and analysis, Microsoft Excel 2019 software was used to organize and format the data collected from the KoboToolbox platform. Subsequently, Jamovi and GraphPad Prism software were utilized with specialized packages to process the data according to specific objectives. These tools were selected for their flexibility in handling data and the quality of the expected results.

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

## 4. Determinants of Urban Vulnerability

Urban vulnerability results from the interaction between natural, physical, social, economic, institutional, and technological factors. It is a multidimensional phenomenon, where each vulnerability reinforces the others. Understanding these factors, therefore, makes it possible not only to measure a city's level of vulnerability but also to design more effective adaptation and resilience strategies.

### *4.1. Socio-Economic Factors*

The socio-economic conditions of inhabitants strongly influence their level of vulnerability. In many developing cities, urban poverty and the rapid expansion of informal settlements create entire areas lacking basic services. Poor populations, often forced to occupy risky land (flood zones, ravines, unstable outskirts), are the first to be exposed to hazards. Dependence on the informal sector, characterized by precarious incomes and a lack of social protections, limits households' ability to adapt to crises. Finally, inequalities in access to housing, education, and healthcare amplify disparities and reinforce urban fragilities. From a mathematical point of view, the economic impact on urban vulnerability could be modeled as a function of several independent variables.

$$\mu = \sum_{i=1}^{n} wi \; x \; Ii \qquad (2)$$

Where ***Ii*** is the normalized value of the indicator and **Wi** is the weight associated with that indicator. The final index often varies between 0 (low vulnerability) and 1 (high vulnerability).

### *4.2. Demographic Factors and Urbanization*

Urban areas at risk are characterized by their exposure to various types of natural and anthropogenic hazards. These risks can be exacerbated by factors such as:

- Urban density: Areas with high population density, where evacuation is difficult and emergency services are overwhelmed.
- Inadequate infrastructure: Aging buildings or buildings constructed with poor-quality materials.
- Proximity to natural hazards: Cities located near coastlines, hillsides prone to landslides, or near seismic zones.

Rapid urbanization in risk areas can increase the vulnerability of resident populations. To understand the impact of this growth, examine the relationship between urbanization and disaster frequency using mathematical models. For example, using a logical predictive model:

$$P\left(\frac{\text{catastrophe}}{\text{urbanisation}}\right) = \frac{e^{\beta 0+\beta 1x}}{1+e^{\beta 0+\beta 1x}} \qquad (3)$$

Where **x** represents the degree of urbanization. This type of analysis makes it possible to predict the probability of a disaster occurring based on the intensity of urbanization.

### *4.3. Climatic and Environmental Factors*

Climate change is a major cause of urban vulnerability. Its impacts are felt not only through increases in temperature and changes in climate patterns but also through more frequent extreme weather events. Climate change poses a growing challenge to cities around the world, particularly those located in coastal areas or river basins [17]. In addition, climate migration can intensify pressure on already limited resources in urban areas and lead to increased competition for housing, jobs, and social services [13].

The environment is a major determinant of urban vulnerability. Cities exposed to natural hazards such as floods, droughts, landslides, and storms are particularly fragile. In the context of climate change, these hazards tend to intensify, increasing the risks to populations and infrastructure. The increasing impermeability of soils linked to uncontrolled urbanization also heightens vulnerability to flooding [26]. The formula below takes into account various climatic and environmental factors.

$$Vclim = (\alpha xT + \beta xE + \gamma C) \qquad (4)$$

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

where: Vclim represents the overall climate and environmental vulnerability score, T is an index of average or extreme temperature (e.g., annual temperature or periods of extreme heat), **E** is an index of exposure to extreme weather events (floods, hurricanes, storms), C is an index of climate change, such as the rate of sea level rise or the frequency of climate-related disasters, and $\alpha$, $\beta$, $\gamma$ are coefficients of importance or weighting, determined according to the specific sensitivity of the area to each factor.

*4.4. Physical and Infrastructural Factors*

A city's vulnerability can also be measured by the quality of its infrastructure and built environment. Precarious housing, which is often unregulated and built without earthquake-resistant or safety standards, increases the risk of damage in the event of natural disasters. In addition, inadequate drinking water, sanitation, electricity, and road networks exacerbate inequalities and undermine the living conditions of urban populations. The location of certain neighborhoods in flood-prone, marshy areas or areas subject to industrial risks (proximity to factories, landfills, etc.) further exacerbates this vulnerability, making certain parts of the city particularly exposed and fragile.

*4.5. Institutional and Governance Factors*

Urban governance is a key lever for reducing or, conversely, exacerbating vulnerability. The absence of urban planning documents (master plans, development plans) or their non-application encourages disorderly urbanization, which is often incompatible with sustainability requirements. The lack of coordination between local and national institutions and development partners leads to fragmented and ineffective management of urban risks. In addition, weak institutional capacities, whether financial, technical, or human, limit the implementation of appropriate policies.

**Table 1.**
Assessment grid for good governance and institutional factors.

| **Institutional & governance factors** | **Indicators** | **Observed value** | **Score (0-5)** | **Weight (%)** | **Weighted score** |
|---|---|---|---|---|---|
| Planning | Existence of planning documents (Yes/No) | Yes/No | 0 or 5 | 20 | =Score×weight |
| Enforcement of standards | Percentage of urban projects that comply with plans | % | (standardized) | 20 | =Score×weight |
| Institutional capacity | Ratio of qualified technical personnel to needs | % | (standardized) | 20 | =Score×weight |
| Financing | Percentage of urban budget allocated to resilient infrastructure | % | (standardized) | 20 | =Score×weight |
| Citizen participation | Percentage of projects incorporating public consultation | % | (standardized) | 20 | =Score×weight |
| Global indices | | | | 100 | = SUM of the weighted values |

*4.6. Technological and Informational Factors*

Finally, urban vulnerability is also linked to technological capabilities and information management. The lack of effective early warning systems prevents populations from preparing for imminent disasters. The lack of reliable data on urban growth, risk mapping, and resource consumption limits planning and prevention. In many contexts, technological innovations such as the digitization of urban services, smart urban planning solutions, and green infrastructure are still largely inaccessible, further exacerbating the lag in adaptation. The technological gap, therefore creates a form of urban vulnerability, particularly in secondary cities in developing countries. Table 2 below provides a summary of the various factors considered.

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

**Table 2.**
Table of vulnerability factors and their calculation methods.

| Factors | Possible indicators | How to measure/calculate them? |
|---|---|---|
| Environmental and climatic | - Frequency of floods/droughts - Area of flood-prone or eroded areas - Loss of vegetation cover (%) | - Climate data (weather, satellite images). - GIS to map exposed areas. - Calculation of annual deforestation rate. |
| Physical and infrastructural | - % of substandard housing - Building density (inhabitants/ha) - Access to drinking water, sanitation, electricity - Length of paved roads per km² | - Household surveys and census - Municipal data/urban plans - Ratio: (households served/total households) × 100 - Infrastructure inventory |
| Socio-economic | - Urban poverty rate (%) - Unemployment rate - Share of informal sector (%) - Average household income | - INSEED/Statistics Institute data - Local socio-economic surveys - Ratio: (population in poverty/total population) × 100 |
| Institutional and governance | - Existence of planning documents (Yes/No) - Budget execution rate (%) - Number of urban projects financed/completed - Transparency and participation index | - Documentary analysis (plans, diagrams) - Administrative accounts/local authority reports - Ratio: (budget executed/budget planned) × 100 |
| Demographic and social | - Population growth rate (%) - Population density (inhabitants/km²) - Share of young people (<25 years old) and vulnerable people - School enrollment rate and access to healthcare | - Population census - Ratio: (population in year N – population in year N-1) / population in year N-1 × 100 - Education/health surveys |
| Technological and informational | - Existence of early warning systems (Yes/No) - % of urban data available in GIS - Rate of digitization of urban services | - Inventory of existing tools - Ratio: (neighborhoods mapped / total number of neighborhoods) × 100 - Analysis of smart city projects |

Measuring all these factors leads to the calculation of the overall vulnerability index, which is the sum of the other indices calculated. The overall vulnerability index generally ranges from 0 to 5 and can be interpreted in various ways. Table 3 below provides an assessment grid for the overall urban vulnerability index, the classification of the level of vulnerability, and its interpretation.

**Table 3.**
Urban vulnerability assessment grid.

| Global index (0-5) | Vulnerability level | Interpretation |
|---|---|---|
| 0.0 – 1.0 | Very low | The city has solid infrastructure, effective governance, and high adaptive capacity. Vulnerability is virtually zero. |
| 1.1 – 2.0 | Low | Some weaknesses exist, but urban resilience remains satisfactory. The city can absorb most shocks. |
| 2.1 – 3.0 | Medium | The city is exposed to several risks but has room for maneuver. Targeted adaptation policies are needed. |
| 3.1 – 4.0 | High | Significant vulnerability linked to structural deficits (infrastructure, poverty, governance). High exposure to crises. |
| 4.1 – 5.0 | Very high | The city is extremely vulnerable: a lack of preparedness, high exposure, and low adaptive capacity. Major risks for the population. |

Table 3, therefore provides a range of metrics that can be used to measure vulnerability in order to make decisions and identify strategies to facilitate urban resilience.

## 4. Results

### *4.1. Climate and Environmental Factors*

Climate change and associated extreme weather events pose a serious threat to natural resources, on which most of the Chadian population depends for their livelihoods. Analysis of Pearson's correlation matrix reveals significant relationships between meteorological variables. Precipitation is strongly correlated with humidity ($r = 0.75$), confirming that rainy days are generally more humid. However, it is negatively correlated with maximum temperature ($r = -0.83$), indicating that heavy rainfall is often associated with cooler temperatures. Humidity itself has a very strong negative correlation with

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

maximum temperature (r = −0.86), suggesting that humid air tends to limit heat peaks. Maximum temperatures are moderately correlated with winds (r ≈ 0.48 for MAX Wind), which may reflect more dynamic and unstable conditions on hot days. Finally, minimum and maximum winds are positively correlated (r = 0.56), showing some consistency in wind patterns. There is a strong positive correlation between rainfall and relative humidity; the higher the rainfall, the higher the humidity. These results are consistent with those obtained by Bolay and Kern [26].

**Table 4.**
Correlation matrix of climate factors.

| | Rain | Humidity | TMAX | TMIN | Wind MAX | Wind MIN |
|---|---|---|---|---|---|---|
| Rain | 1 | | | | | |
| Humidity | 0.74678316 | 1 | | | | |
| TMAX | -0.82598999 | -0.85824484 | 1 | | | |
| TMIN | -0.53178886 | -0.29827548 | 0.57616332 | 1 | | |
| WindMAX | -0.58316275 | -0.52967416 | 0.4815941 | 0.1670448 | 1 | |
| WindMIN | -0.41566561 | -0.55625243 | 0.41195089 | -0.00821156 | 0.5647197 | 1 |

The results in Table 4 show that rainfall is strongly linked to a more humid and cooler atmosphere, with moderate winds. Humidity is inversely linked to heat and winds, which is consistent with rainy conditions. Correlated climatic factors directly or indirectly influence vulnerability.

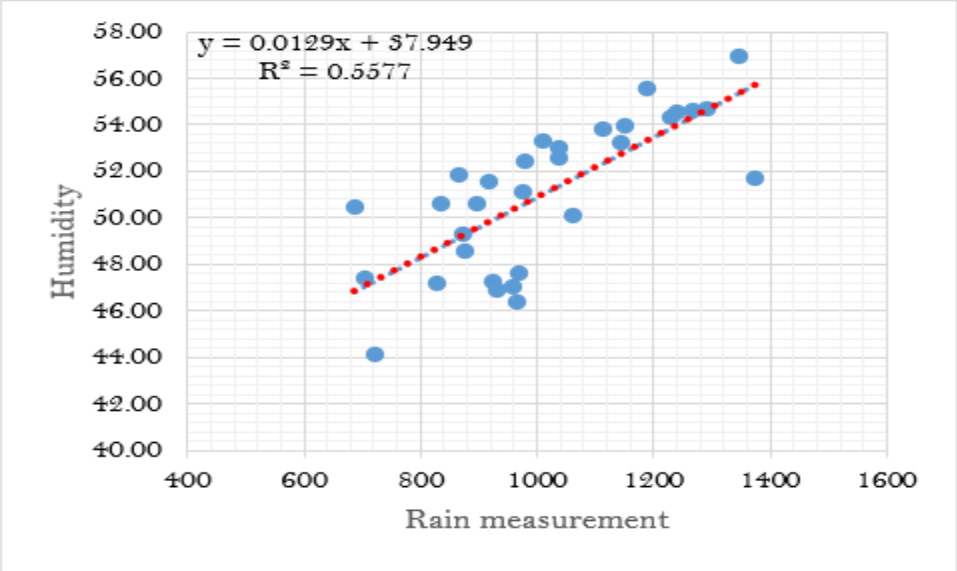


**Figure 3.**
Pearson test results between climatic factors.

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

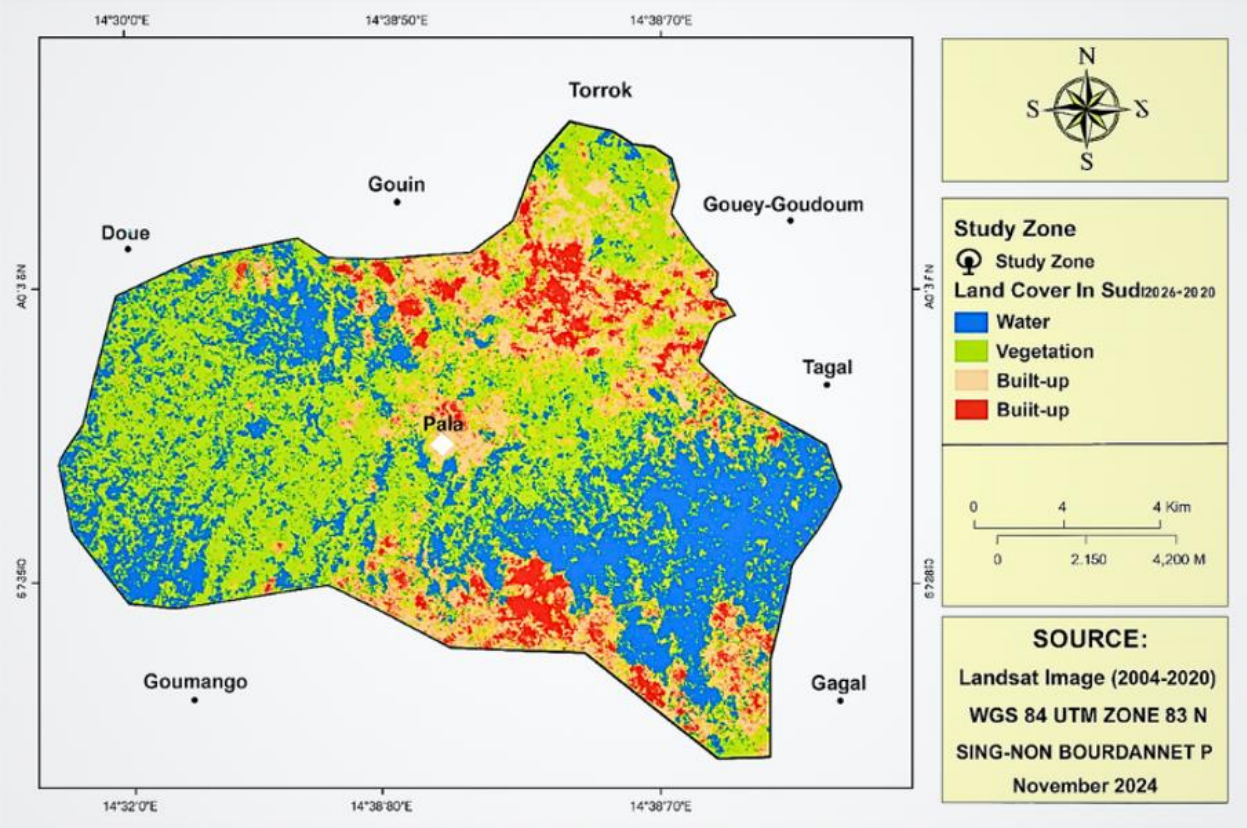


**Figure 4.**
LULC.

The land use dynamics map between 2004 and 2020 shows that urbanization is occurring in an uncontrolled manner and that non-building zones are being occupied during this period. This further exposes populations to the risks of flooding and water erosion. This work is also related to the work of [20].

*4.2. Socioeconomic and Demographic Factors of Urban Vulnerability*

Our research findings show that sparsely populated regions such as Pala have very high poverty rates (≈65%). This trend suggests that concentrated urban areas may offer greater economic opportunities and access to services, thereby reducing social vulnerability. However, this correlation should not obscure internal disparities within cities, where pockets of poverty persist despite density. These results are consistent with the findings of Ahimah-Agyakwah et al. [27], which shows that urbanization in sub-Saharan Africa can reduce poverty, but only if it is accompanied by targeted public investment [27]. Similarly, Dwyer and Sanchez [28] emphasize that the spatial distribution of the population strongly influences poverty dynamics, particularly through migration to urban centers and the effects of territorial segregation [28].

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

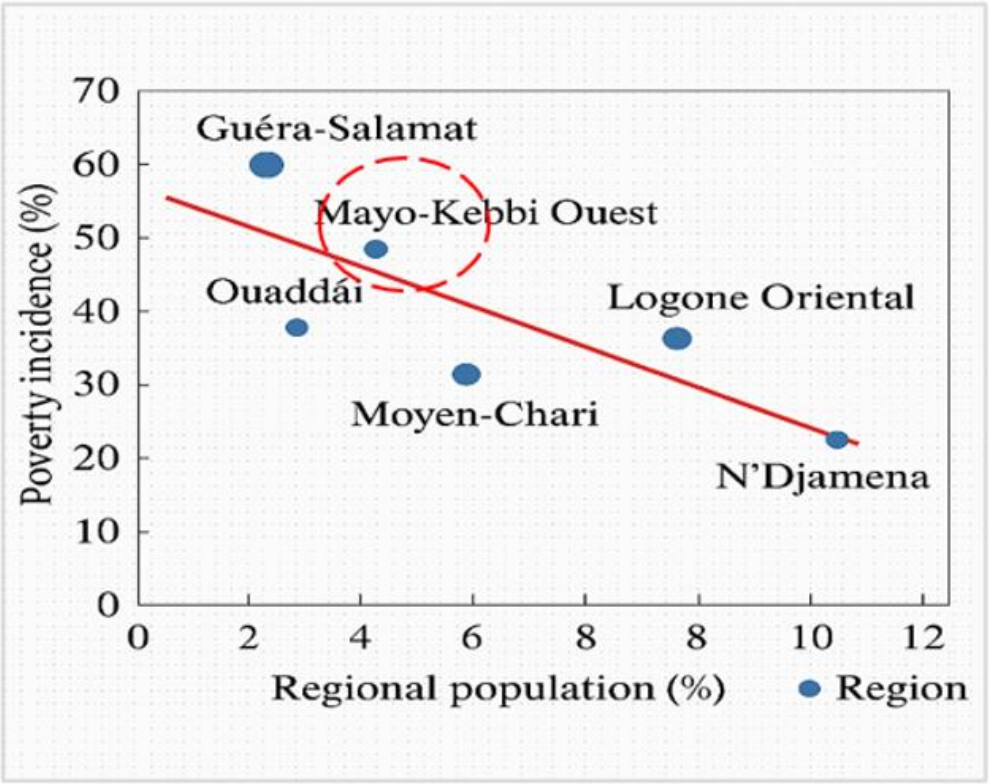


**Figure 5.**
Evolution of the poverty rate.

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

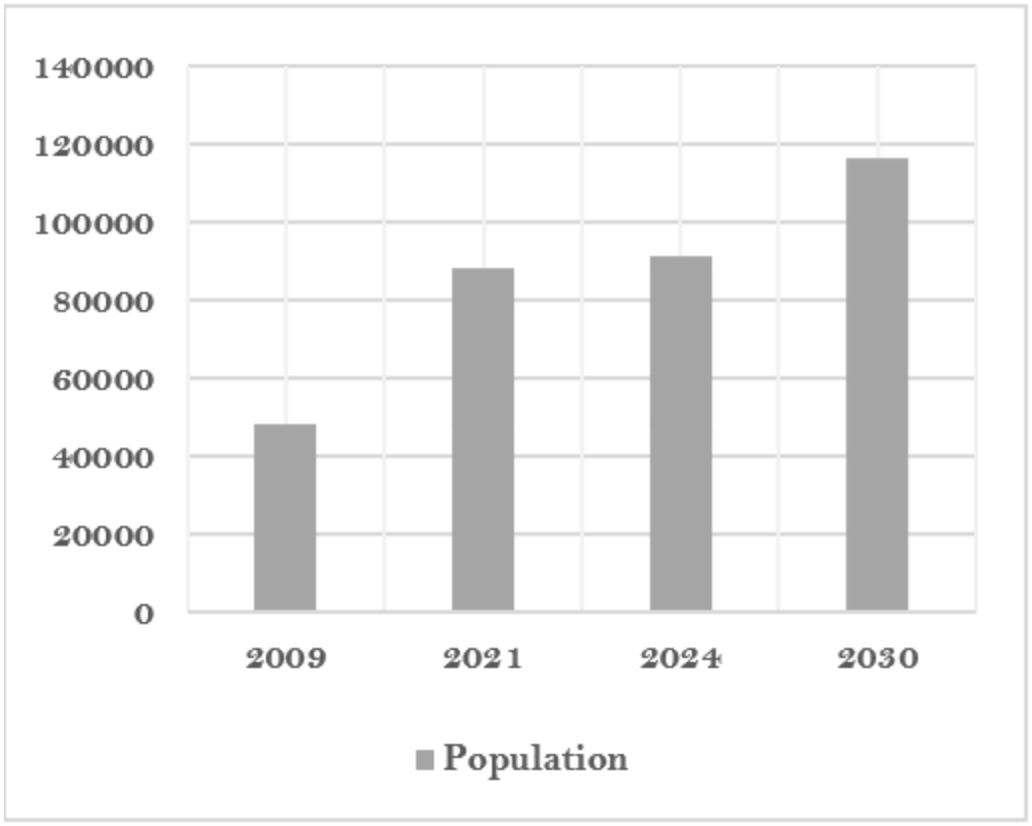


**Figure 6.**
Evolution of the population.

Figures 5 and 6 above show that socioeconomic and demographic factors are exacerbated by other factors that also determine vulnerability. With such a high poverty rate as shown in Figure 5, it must be said that the means to address certain cases of vulnerability are virtually non-existent. However, the population curve in Figure 6 remains on trend, with an annual growth rate of over 3.6%. This same issue was addressed by Smit and Wandel [29].

*4.3. Physical and Infrastructural Factors*

The physical and infrastructural factors of urban vulnerability relate to the quality of buildings, the condition of networks and facilities, and their ability to meet the needs of populations and withstand hazards. They are a central element of the analysis, as weak basic infrastructure and precarious housing considerably increase the exposure and sensitivity of cities to risks. The results of the study show that only 7% of the built environment of those surveyed in the city of Pala is in good condition, compared to 63% in average condition and 30% in poor condition. This could potentially increase vulnerability. As for access to basic urban services, there is still a large gap compared to Chadian cities of the same size as Pala. It has no electricity supply, and the rate of access to drinking water is still below 30%. The sanitation system, both liquid and solid, remains inadequate.

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

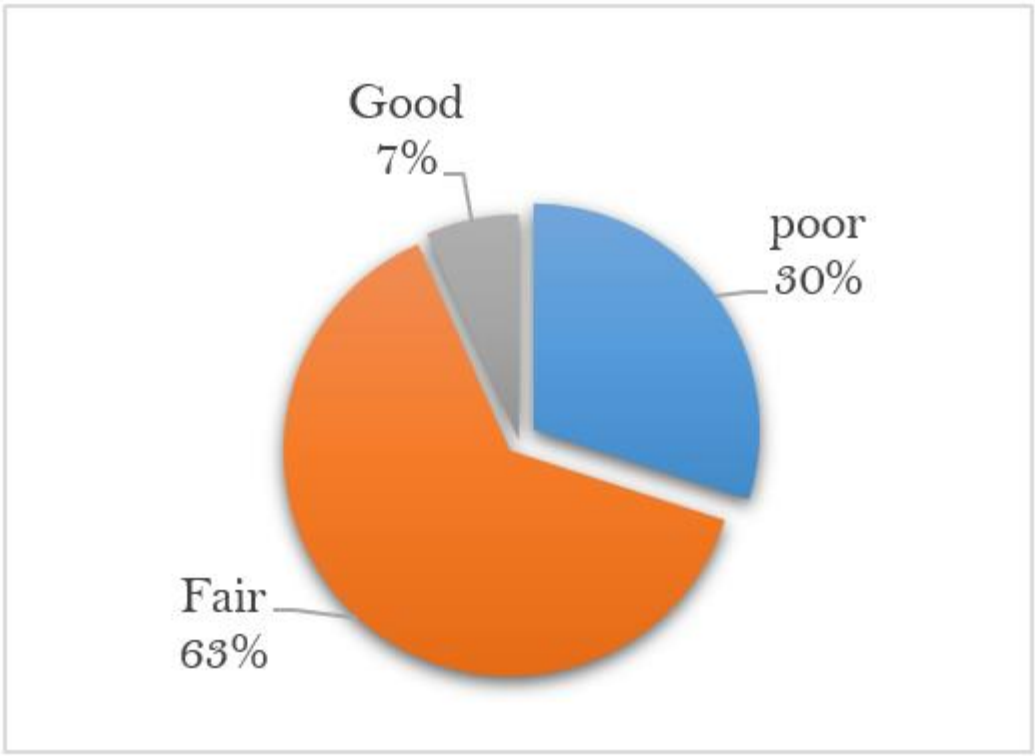


**Figure 7.**
State of the built environment in the city of Pala.

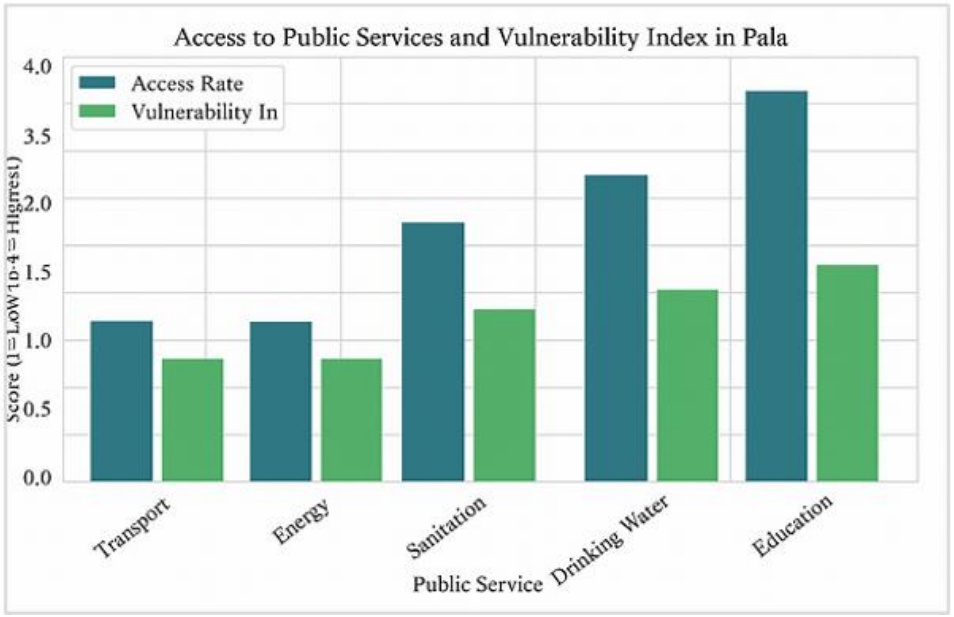


**Figure 8.**
Access to basic urban services.

Figure 7 provides an overview of the built environment in the city of Pala. Buildings are often constructed of rammed earth bricks and generally have strip footings. These buildings are often less

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

resistant to erosion and weathering of all kinds. Roofs are often made of straw and rarely of sheet metal or other conventional materials. Figure 8 provides information on access to various basic urban services in the city of Pala. These results correlate with those of D'Ercole, et al. [30].

*4.3. Institutional and Governance Factors*

Institutional and governance factors determine the extent to which urban policies can be planned, financed, and implemented effectively. They influence the sustainability and resilience of cities in the face of shocks. Despite the existence of the municipal development plan, its implementation remains an issue that needs to be explored carefully. The table below provides an overview of the PDC for the municipality of Pala.

**Table 5.**
Assessment report on good governance and institutional factors.

| Strategic Axes | Number Of Planned Projects | Number Of Projects Completed | Rate % | Ecart% | Justification/Explanation of Disparities | Observations Or Measures Taken |
|---|---|---|---|---|---|---|
| Governance | 11 | 4 | 36% | - 64% | The negative gap can be explained by low funding. Only projects implemented by partners ZONAL, APLFT, and GIZ PRCPT supported the municipality's actions. | The concept of governance is in its infancy in Chad, and few citizens understand it. It is essential to initiate related projects in PDC 2. |
| Urbanization, urban roads, electricity, and water network | 05 | 06 | 120% | + 20% | Several studies have been conducted with the intention of taking action in this area, which presents numerous challenges. | This area requires an in-depth preliminary assessment in conjunction with the key decentralized department responsible for infrastructure, urban planning, etc. |

Initially planned to last six years, the PDC only lasted five years due to delays in its approval. The overall assessment of the implementation of the Pala Commune Development Plan took place upon its expiration. The failure observed in the governance section is explained by the lack of participation and inclusion of the local community in the process of drafting governance and urban planning documents [31]. These results are similar to a case study conducted in South Africa by Kato and Manchidi [32].

*4.4. Strategies For Adapting to Urban Vulnerability*

Pala perfectly illustrates the challenges facing secondary African cities in terms of urban vulnerability: a combination of physical risks, infrastructure deficits, and fragile governance. Table 6 below presents the normal strategies desired for cities in general and, therefore applicable to the city of Pala. This list of strategies, while not exhaustive, can be combined with local practices to provide more choices or flexibility.

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

**Table 6.**
Urban vulnerability assessment form.

| Domain | Strategy | Objective |
|---|---|---|
| Environment | Participatory mapping of risk areas | Anticipate flooding and erosion |
| Infrastructure | Rehabilitation of water points and latrines | Improve sanitary conditions |
| Urban planning | Creation of local development plans | Organize urban expansion |
| Community | Awareness-raising and training for residents | Strengthen social resilience |
| Governance | Support for decentralization and local capacities | Strengthen autonomy and responsiveness. |

Looking at this table, we can adapt it to the city of Pala according to local realities, specificities, and available resources. The case of Pala also shows that local, participatory, and well-targeted strategies can transform vulnerability into a lever for resilience. With an overall score of 0.5/5, the city of Pala has few adaptation strategies in place to address various urban vulnerabilities. The strategies are multifaceted but can be summarized in Table 7 below for the case of the city of Pala.

**Table 7.**
Adaptation strategies applicable to Pala.

| Type of factor | Consequences | Adaptation strategy | Stakeholders |
|---|---|---|---|
| Physical | Seasonal flooding, unstable soil | - Water drainage<br>- Construction of retention basins<br>- Soil reinforcement<br>- Construction of gutters | -Municipality<br>-Population<br>-NGO |
| Infrastructural | Poor access to water, deteriorated roads | - Development of urban roads and tracks<br>- Adoption of a rainwater harvesting technique | -Municipality<br>-Population<br>-NGO |
| Institutional | Centralized governance, poor planning | - Decentralization of tasks with local associations<br>- Promotion of inclusion and citizen participation in various projects. | -Municipality<br>-Population<br>-NGO |

The responses implemented in Pala often remain sectoral and ad hoc. A few community initiatives, supported by NGOs, have made it possible to rehabilitate water points and raise awareness among residents about climate risks. Participatory mapping efforts have been launched to identify areas at risk. However, these actions lack strategic coherence and sustainable institutional support. The lack of long-term funding, the low level of involvement of local authorities in planning, and the lack of reliable data are hindering the implementation of effective adaptation policies. These findings are consistent with the work of Turner et al. [33], who approach this issue from a different angle.

## 5. Discussion

Urban vulnerability in secondary cities in Chad, such as Pala, is a major challenge in a context of rapid population growth, climate pressure, and weak institutional capacities. Unlike capitals or large metropolitan areas, these cities are often less visible in national policies, but they are the focus of critical social and environmental dynamics [33].

The analysis of urban vulnerability in Pala confirms that secondary African cities are places where both structural fragilities and adaptation potential are concentrated. Vulnerability is multidimensional, combining environmental, physical, socioeconomic, and institutional factors, as Turner, et al. [34] point out in their conceptual framework of vulnerability, which highlights exposure, sensitivity, and adaptive capacity.

Physically speaking, the precarious nature of buildings and the lack of infrastructure exacerbate the risks. Studies by Douglas, et al. [35] and Hardoy and Pandiella [36] show that in many cities in the Global South, the absence of drainage systems and the proliferation of informal settlements in high-risk areas amplify the effects of floods and droughts. Pala illustrates this pattern with neighborhoods built

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

on flood-prone land and sewage systems that are virtually non-existent or made with rudimentary community resources.

The socioeconomic dimension is another determining factor. According to Moser [37] and Adger [38], urban poverty significantly reduces households' ability to protect themselves and bounce back after a shock. In Pala, where a large part of the population depends on the informal sector, incomes are low and irregular, confirming the findings of Chambers, et al. [38] on the close link between poverty and vulnerability.

At the institutional level, governance challenges exacerbate this vulnerability. As noted by Simon [39] and Collord et al. [41], weak local administrations, lack of coordination between actors, and dependence on external funding are characteristic features of secondary African cities. The case of Pala illustrates these limitations: although planning documents exist, they are rarely implemented, echoing the findings of Folke, et al. [40] on the low rate of implementation of master plans in small African cities.

Nevertheless, it would be simplistic to consider Pala as solely vulnerable. As Folke, et al. [40] point out, urban systems have endogenous adaptive capacities based on local knowledge, social networks, and community dynamics. Water management cooperatives and mutual aid practices between families in times of crisis are concrete examples of resilience, similar to the observations of Marais, et al. [41] on the role of communities in risk management in secondary cities in Africa.

Furthermore, research by Smit and Wandel [29] and Carmin, et al. [31] emphasizes the need to integrate local adaptation strategies into formal urban policies. In Pala, this integration remains in its infancy, but it is a promising avenue for strengthening resilience. Recent literature by Satterthwaite [21] emphasizes the importance of participatory and inclusive approaches, which help to anchor adaptation in the realities experienced by residents.

Thus, the case of Pala illustrates a paradox: significant structural vulnerability but also underestimated local adaptation capacities. As Satterthwaite [21] notes, adaptation should not only be seen as a technical response but as a social and political process that involves choices of governance and justice. For secondary cities in Chad, strengthening resilience therefore requires combining three levers: investment in appropriate and sustainable urban infrastructure, institutional strengthening and inclusive governance, and the promotion of local and community initiatives.

## 6. Conclusion

Urban vulnerability in secondary cities in Chad, such as Pala, is a strategic issue in a context of rapid population growth, increased climate pressure, and weak institutional capacities. Unlike large cities, these secondary cities are often marginalized in national policies, even though they are hubs for critical territorial dynamics. In Pala, this vulnerability manifests itself through a combination of physical, infrastructural, and institutional factors. Heavy rains, exacerbated by the lack of effective drainage systems, illustrate the fragility of the urban fabric in the face of climatic hazards. Basic infrastructure (drinking water, sanitation, roads) is inadequate or degraded, limiting access to essential services and worsening living conditions. However, beyond material deficits, local governance plays a decisive role. Centralized decision-making, lack of coordination between stakeholders, and the absence of formal urban planning make it difficult to anticipate risks. This vulnerability is therefore structural, not simply circumstantial. In response to this situation, several adaptation strategies have been identified or initiated, although they are often fragmented.

These actions, while promising, lack strategic coherence and sustainable institutional support. The absence of long-term funding, the low level of involvement of local authorities in planning, and the lack of reliable data are hindering the implementation of effective adaptation policies. For secondary cities such as Pala to strengthen their resilience, it is essential to adopt an integrated, territorialized, and inclusive approach. This involves climate-sensitive urban planning based on local data and participatory tools, institutional capacity building through decentralization, and the active involvement of local

*Edelweiss Applied Science and Technology*
*ISSN: 2576-8484*
*Vol. 9, No. 10: 306-323, 2025*
*DOI: 10.55214/2576-8484.v9i10.10403*

communities in defining priorities and solutions. With this in mind, several recommendations can be made. First, it is crucial to recognize the role of secondary cities in national planning and development policies at the political level. Next, investment must be made in basic infrastructure, targeting the most vulnerable neighborhoods. Training for residents in risk management and resilience must be systematized, drawing on local knowledge and community dynamics.

Finally, the establishment of a local vulnerability observatory, based on participatory and accessible data, would help guide decisions and assess progress. Pala should not be seen solely as a vulnerable city but as a territory of innovation and resilience. Through inclusive governance, climate-sensitive planning, and community mobilization, it can become a model of transformation for secondary cities in Chad.

## Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

## Copyright:



## References

[1] G. Josse, "Planning and managing African cities: What place for technological innovations?," 2021.
[2] A. Guterres, "We need an inclusive, people-centered approach to planning, building, and managing cities," 2023.
[3] La Vulnérabilité Territoriale, "Territorial vulnerability: A new approach to risks in urban environments," *Cybergeo, Mars*, 2009.
[4] I. Maket, I. S. Kanó, and Z. Vas, "Quality of urban infrastructural service accessibility and human well-being in Sub-Saharan Africa," *World Development Sustainability*, vol. 4, p. 100155, 2024. https://doi.org/10.1016/j.wds.2024.100155
[5] C. Ghorra-Gobin, "Preventive urban planning: Documenting environmental and health inequalities at the metropolitan level and reinventing nature in the city," *Bulletin de l'association de géographes français. Géographies*, vol. 99, no. 99-4, pp. 519-533, 2023. https://doi.org/10.4000/bagf.10145
[6] I. Bah and R. L. Teguia Kenmegne, "Normative pluralism and socio-environmental vulnerability in cameroon: A literature review of urban land policy issues and challenges," *Urban Science*, vol. 9, no. 6, p. 219, 2025. https://doi.org/10.3390/urbansci9060219
[7] L. Y. Mopaté, M. Tellah, A. B. Bechir, and A. Nayo, "Characterization of the pork sector in the towns of Pala and Moundou in the savannah zone of southwest Chad," *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, vol. 73, no. 1, pp. 3-10, 2020. https://doi.org/10.19182/remvt.31291
[8] O. D. Sané, A. T. Gaye, M. Diakhaté, and M. Aziadekey, "Social vulnerability assessment to flood in Medina Gounass Dakar," *Journal of Geographic Information System*, vol. 7, no. 4, pp. 415-429, 2015. https://doi.org/10.4236/jgis.2015.74033
[9] e. a. Janicot S., *Chapitre 13. Zones urbaines: Des mégapoles vulnérables in changement climatique*. Paris, France: IRD Éditions, 2015.
[10] I. Mballo, O. Sy, and B. Barry, "Vulnerabilities and adaptation strategies of farmers facing socio-environmental changes in Haute Casamance (Southern Senegal)," *Belgeo. Revue belge de géographie*, no. 2, 2021. https://doi.org/10.4000/belgeo.48429
[11] B. Barroca, M. DiNardo, and I. Mboumoua, "From vulnerability to resilience: Mutation or upheaval?," *Echogeo*, no. 24, 2013. https://doi.org/10.4000/echogeo.13439
[12] B. Quenault, "Vulnerability, a central concept in the analysis of urban risks linked to climate change," *The Annals of Urban Research*, vol. 110, no. 1, pp. 138–151, 2015. https://doi.org/10.3406/aru.2015.3175
[13] J. M. Diaz-Sarachaga and D. Jato-Espino, "Analysis of vulnerability assessment frameworks and methodologies in urban areas," *Natural Hazards*, vol. 100, no. 1, pp. 437-457, 2020. https://doi.org/10.1007/s11069-019-03805-y
[14] L. D. Olvera, D. Plat, and P. Pochet, *Urban sprawl, poverty situations, and access to the city in sub-saharan africa: The example of niamey* (no. Chapitre 7). Paris, France: L'Harmattan, 2002, pp. 147-175.
[15] İ. Çal and A. Ciravoğlu, "Determining vulnerability indicators of buildings for sea-level rise and floods in urban coastal areas," *Sustainability*, vol. 17, no. 1, p. 27, 2024. https://doi.org/10.3390/su17010027

[16] K. Krellenberg, J. Welz, F. Link, and K. Barth, "Urban vulnerability and the contribution of socio-environmental fragmentation: Theoretical and methodological pathways," *Progress in Human Geography*, vol. 41, no. 4, pp. 408-431, 2017. https://doi.org/10.1177/0309132516645959
[17] J.-C. Thouret and R. D'ercole, "Vulnerability to natural hazards in urban areas: Effects, factors and social responses," *Cahiers des sciences humaines. ORSTOM*, vol. 32, no. 2, pp. 407-422, 1996.
[18] É. Denis, "Qualifying rapidly expanding urban areas in the South," *L'Espace géographique*, vol. 44, no. 4, pp. 307-324, 2015.
[19] A. K. Magnan and T. W. Dale, *Global progress on adaptation and outlook in adaptation gap report 2020*. Geneva. : United Nations, 2021. https://doi.org/10.18356/9789280738346c011
[20] F. Renard and P.-M. Chapon, "An urban vulnerability assessment method applied to the Lyon metropolitan area," *L'Espace géographique*, vol. 39, no. 1, pp. 35-50, 2010. https://doi.org/10.3917/eg.391.0035
[21] D. Satterthwaite, *The transition to a predominantly urban world and its underpinnings* (no. 4). Lied, 2007.
[22] D. Satterthwaite *et al.*, "Building resilience to climate change in informal settlements," *One Earth*, vol. 2, no. 2, pp. 143-156, 2020. https://doi.org/10.1016/j.oneear.2020.02.002
[23] E. Giorgi, T. Cattaneo, and K. P. Serrato Guerrero, "The principles of design for vulnerable communities: A research by design approach overrunning the disciplinary boundaries," *Buildings*, vol. 12, no. 11, p. 1789, 2022. https://doi.org/10.3390/buildings12111789
[24] R. V. Attipo, I. J. Emvoulou, and A. C. Coffi, "Climate change and urban stormwater: vulnerability analysis of the 2010 floods in Lomé, Togo," *Frontiers in Climate*, vol. 5, p. 1281433, 2023. https://doi.org/10.3389/fclim.2023.1281433
[25] V. Watson, "Locating planning in the New Urban Agenda of the urban sustainable development goal," *Planning Theory*, vol. 15, no. 4, pp. 435-448, 2016. https://doi.org/10.1177/1473095216660786
[26] J.-C. Bolay and A. Kern, "Technology and cities: What type of development is appropriate for cities of the south?," *Journal of Urban Technology*, vol. 18, no. 3, pp. 25-43, 2011. https://doi.org/10.1080/10630732.2011.615563
[27] S. Ahimah-Agyakwah, E. Nketiah-Amponsah, and F. Agyire-Tettey, "Urbanization and poverty in Sub-Saharan Africa: Evidence from dynamic panel data analysis of selected urbanizing countries," *Cogent Economics & Finance*, vol. 10, no. 1, p. 2109282, 2022. https://doi.org/10.1080/23322039.2022.2109282
[28] R. E. Dwyer and D. Sanchez, *Population distribution and poverty », in international handbook of migration and population distribution, vol. 6, M. J. White, éd., in international handbooks of population*. Dordrecht: Springer Netherlands, 2016.
[29] B. Smit and J. Wandel, "Adaptation, adaptive capacity and vulnerability," *Global Environmental Change*, vol. 16, no. 3, pp. 282-292, 2006. https://doi.org/10.1016/j.gloenvcha.2006.03.008
[30] R. D'Ercole, S. Hardy, P. Metzger, and J. Robert, "Urban vulnerabilities in Andean countries general introduction," *Bulletin de l'Institut Français d'études Andines*, vol. 38, no. 38, pp. 411-420, 2009.
[31] J. Carmin, D. Dodman, and E. Chu, "Urban climate adaptation and leadership: From conceptual understanding to practical action," Development Working Papers, 2013.
[32] A. I. Kato and N. H. Manchidi, "Navigating the path to sustainable supply chains: A quantitative study of barriers and enablers in South African listed companies," *International Journal of Management and Sustainability*, vol. 14, no. 1, pp. 258-285, 2025. https://doi.org/10.18488/11.v14i1.4139
[33] S. Bronfort, *Adaptation strategies to flood risk in spontaneous settlement areas of Ouagadougou*. Burkina Faso, 2017.
[34] B. L. Turner *et al.*, "A framework for vulnerability analysis in sustainability science," *Proceedings of the National Academy of Sciences*, vol. 100, no. 14, pp. 8074-8079, 2003. https://doi.org/10.1073/pnas.1231335100
[35] I. Douglas, K. Alam, M. Maghenda, Y. Mcdonnell, L. McLean, and J. Campbell, "Unjust waters: Climate change, flooding and the urban poor in Africa," *Environment and Urbanization*, vol. 20, no. 1, pp. 187-205, 2008. https://doi.org/10.1177/0956247808089156
[36] J. Hardoy and G. Pandiella, "Urban poverty and vulnerability to climate change in Latin America," *Environment and urbanization*, vol. 21, no. 1, pp. 203-224, 2009.
[37] C. O. Moser, "The asset vulnerability framework: reassessing urban poverty reduction strategies," *World development*, vol. 26, no. 1, pp. 1-19, 1998.
[38] N. Chambers *et al.*, "Validation of the self-report quantified Tuberous Sclerosis Complex-Associated Neuropsyciatric Disorders Checklist (TAND-SQ)," *Orphanet Journal of Rare Diseases*, vol. 20, no. 1, p. 304, 2025.
[39] D. Simon, "Urban environments: issues on the peri-urban fringe," *Annual Review of Environment and Resources*, vol. 33, no. 1, pp. 167-185, 2008.
[40] C. Folke, S. R. Carpenter, B. Walker, M. Scheffer, T. Chapin, and J. Rockström, "Resilience thinking: Integrating resilience, adaptability and transformability," *Ecology and Society*, vol. 15, no. 4, p. 20, 2010.
[41] L. Marais, E. L. Nel, and R. Donaldson, *Secondary cities and development*. London: Routledge 2016.