

## **RAINWATER MANAGEMENT PROBLEMS IN CITIES IN DEVELOPING COUNTRIES: THE CASE OF THE MUNICIPALITY OF ZIGUINCHOR, SENEGAL**

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**Abstract:** Senegalese cities are experiencing very rapid growth in terms of both spatial and demographic development, which has an impact on the management of runoff water, which is increasingly a major concern of authorities and urban populations. In these cities, public sanitation infrastructure is insufficient and unevenly distributed in urban space. The objective of this study is to characterize the problem of rainwater management in the city of Ziguinchor (southern Senegal). The methodology is based on an administration, a questionnaire submitted to 288 heads of households, and an interview guide with 13 actors who stand out in the environmental management component at the local level. The results obtained attest to a real problem of sanitation of rainwater managed in precarious conditions due to the lack of infrastructure and water management methods used by households. The

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infrastructural problem is a factor in the poor management of rainwater in Ziguinchor, while rainwater drainage practices do not protect the living environment of the populations. In the city of Ziguinchor, the main strategies adopted in the face of the sanitation network deficit are based on backfilling, the laying of sandbags and stones, evacuation through buckets.

**Key words:** management, rainwater, flooding, infrastructure, strategy, Ziguinchor

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## INTRODUCTION

Access to sanitation is a daily struggle for hundreds of thousands of urban dwellers, particularly in developing countries (ANSD, 2014; Gomis et al., 2019). According to a World Health Organization (WHO, 2009) report, "1.1 billion people or 17% of the world's population lack access to safe drinking water and 2.6 billion or 42% of the world's population lack access to adequate sanitation. Many urban households rely on traditional methods for water supply and sanitation for excreta disposal. Africa is most affected by large regional inequalities on sanitation targets. Of all regions, sub-Saharan Africa has the lowest coverage (< 50%) of safe drinking water (Kaka, 2014). At least 86 million people still practice open defecation and 136 million people do not use improved sanitation services (Kaka, 2014).

In such a context, we understand the importance of questioning the impacts of climate change (CC) on urban water-related uses and services. The meteorological phenomena that can affect the performance or level of service of urban water infrastructure are essentially those: 1) which will modify the volumes and quality of water (surface or groundwater) available; 2) which will affect the abstraction capacity of the catchment structures; 3) which will have an impact on the demand for drinking water; 4) whose intensities and / or durations will be such that they will exceed the evacuation capacities of the rainwater collection networks and 5) which will lead to degradation of the receiving environment at the wastewater discharge points (treated domestic water, rainwater and / or overflow water from unit networks) ((Kaka, 2014; ANSD, 2014; Gomis et al, 2019). The typical meteorological events to be considered are therefore: 1) intense rain events, 2) periods of low rainfall, 3) periods of heatwave and also, more marginally, 4) episodes of winter rain.

Senegal is one of the countries where a low proportion of the population has access to adequate sanitation systems. The collective sewerage networks built by the National Sanitation Office in Senegal (ONAS) cover only a part of urban users, i.e. about 46,240 households throughout the country (ONAS; 2011< Sané, 2018). The evolution of the proportion of access is currently low and lower than expected. This is a major concern for Senegal. The public authorities still do not have quality sanitation systems for sustainable wastewater management. Thus, Vennetier (Vennetier, 1991) states that: "This deficiency is particularly worrying in several areas and endangers the health of thousands of people. The problems posed by water are more acute in terms of both its form and its disposal. This lack of access to water on the one hand and sanitation on the other is the main cause of death among children under 5, the

elderly, and pregnant women (Gomis et al., 2019; Gomis and Thior, 2020). As a result, populations living in informal settlements are the most affected (Soro and Vei, 2017). It is in this sense that Faye (2014) points out that 'the inadequacy of public infrastructure almost hits the most disadvantaged strata, and that the lack of a policy in place increases the unconditional discharge of domestic wastewater into the environment'.

Like all Senegalese cities, Ziguinchor (with a population of nearly 205,294 (ANSD, 2014) is no exception. It is located in the south-west of Senegal between meridians 16° and 17° and parallels 12° and 13°, with an average altitude of 19.30 m. It is bounded to the north by the Casamance River, to the south by the commune of Niaguis, to the west by the Djibélor backwater and to the east by the Boutoute backwater (Figure 1). It has experienced exponential urban growth since the 1970s, 1980s and 1990s, with an urbanisation rate of 51.1%, which is above the national average of 47.5% (ANSD, 2014). The city of Ziguinchor is characterised by a highly contrasted urban fabric, with low, medium and high standard neighbourhoods, as well as non-regulatory and informal settlements generally made of salvaged materials (Gomis and Thior, 2020). These so-called informal settlements are located outside of any planning. Their informal nature means that these neighbourhoods are not equipped with collective sanitation systems by the authorities, who refuse to endorse illegal forms of land occupation (Gomis et al., 2019; Sall and Sy, 2015). The problems of accessibility to drinking water in terms of cost and distance on the one hand, and the lack of adequate sanitation facilities, on the other hand, arise. In addition, we note the frequent flooding in winter due to the absence of drainage channels, problems that constitute an obstacle to the socio-economic development of the neighbourhoods (Sané, 2018; Sané et al., 2019).

Water, sanitation and hygiene are rights for everyone, regardless of the country they belong to. In developing countries, people are denied the rights. This has led to poverty, disease and death, especially among children (Faye et al., 2018). In Ziguinchor, the situation remains the same, enormous difficulty in disposing of excess water. Two small spatial entities with similar physical characteristics, Santhiaba and Belfort, suffer the consequences of the history of their installation on a vulnerable site. The configuration of the city leaves these entities vulnerable to flooding. On the one hand, they constitute a natural receptacle for rainwater from neighbouring districts such as Tiléne, Kandialang and Néma. On the other hand, the recent high rainfall recorded in the commune means that today the inhabitants of these neighbourhoods suffer from excess water (Sané, 2018; Sané et al., 2019).

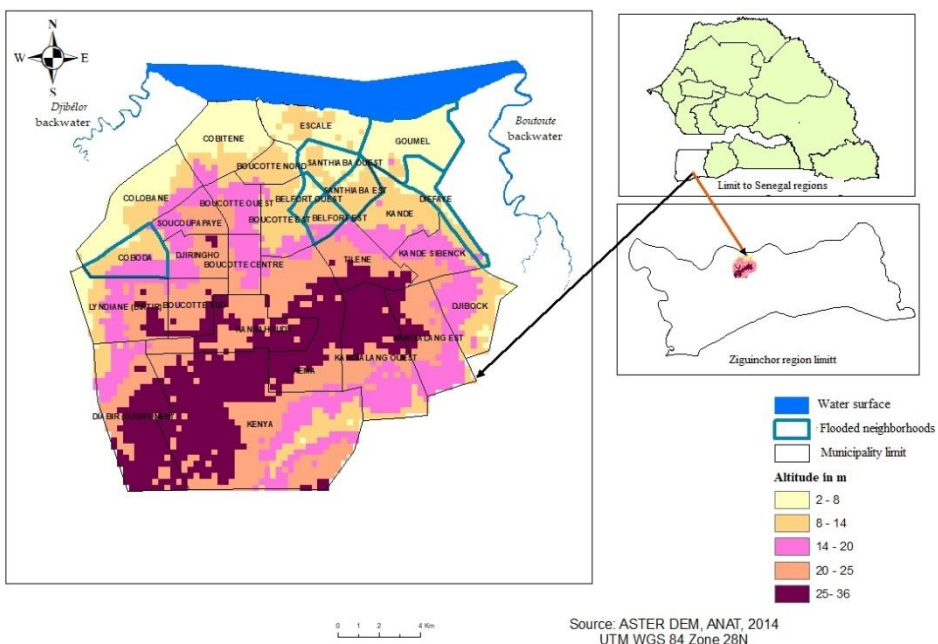
The sanitation system used by the majority of households remains autonomous. The absence of rainwater and domestic wastewater drainage channels, drainage networks and retention basins means that some households feel obliged to use spontaneous techniques as coping strategies. The objective of this study is to characterise the problem of rainwater management in the neighbourhoods of the city of Ziguinchor in southern Senegal). In order to achieve this objective, this study will first analyze the existing public and private sanitation infrastructure, and secondly the rainwater management methods used by households in the city of Ziguinchor. Thus, it is necessary to ask what tools are used to collect and evacuate stagnant water in the city of Ziguinchor? And what methods of rainwater disposal are used by households in Ziguinchor?

This study shows that the problem of rainwater management is intrinsically linked to the question of user participation, the mobilization of local actors, their awareness of this lived, perceived or unknown risk. In this study, we sought to highlight the problems of stormwater management in a secondary town in Senegal. Many cities in Senegal are chronically hard hit by runoff. Such a study is fundamental insofar as it provides a well-documented database on the problem of rainwater management, which is so important for the definition of suitable strategies to fight against floods. This study is based on documentary research, observation and field surveys, and analysis of the results obtained.

## DATA AND METHODS

### Study area

The city of Ziguinchor is located in the south-east of Senegal, embraced by the Casamance River to the north, the commune of Niaguis to the east, the village of Djibélôr to the west and the commune of Boutoupa Camaracounda to the south. A former Portuguese town, Ziguinchor has a melting pot population, the majority of who are Joola. It is influenced by a sub-Saharan climate which makes it the rainiest area (isohyets above 1000mm) compared to other parts of the country. Its proximity to the sea gives it a particular micro-climate, with a feeling of coolness during the months of December, January, February and March. The hydrographic network is mainly formed by the Casamance River in the North and its small tributaries, namely the Boutoute and Djibelor backwaters respectively in the East and West of the city. Since its creation until today, Ziguinchor had 27 districts according to the latest census of the National Agency for Statistics and Demography in 2013.



**Figure 1.** Location and presentation of the city of Ziguinchor and the neighbourhoods surveyed (Source: Gomis, 2021)

The problem of sanitation is particularly acute in Ziguinchor, which is one of the stations with the highest rainfall in the country (1,500 to 2,000 mm per year). This rainfall is often the cause of heavy runoff and exposes certain areas of the city to the risk of flooding, a phenomenon caused by the stagnation or anarchic runoff of rainwater. This means that, despite a rainwater drainage network, the collection, treatment and evacuation of urban wastewater and rainwater remain an equation with several unknowns, both for the municipal authorities and for the population. And if some people blame the population and point the finger at certain behaviours that are the antithesis of good environmental practices, the latter, on the other hand, point to the failures of a sewage system combined with the absence of an adequate sewage network for wastewater or rainwater. During each winter season, the populations of several districts of Ziguinchor get stuck in the water.

**Materials and Methods**

The methodology adopted consists of collecting socio-economic data from the population through surveys and interviews. The initial data, i.e. the data that enabled us to carry out our survey, were obtained from the ANSD (National Agency for Statistics and Demography). The collection of socio-economic data was done on the basis of household surveys in the two districts (Table 1). The questionnaire was submitted to 288 heads of households (men and women) in both Belfort and Santhiaba. The reason for choosing the city of Ziguinchor, and the Santhiaba and Belfort neighbourhoods, is that these two neighbourhoods constitute a very important spatial unit of observation for this study. The neighbourhoods covered by the study were chosen according to the type of housing. Some neighbourhoods were selected on the basis of their predominantly progressive housing and others on the basis of their status as residential neighbourhoods. As a result, the main questions of the questionnaire referred to the existing public and private sanitation infrastructure (collection tools), the wastewater management methods used (stormwater drainage methods). Thus, the data obtained were grouped and processed to finally constitute the sampling frame for the results of this research.

**Table 1.** List of questions used in the questionnaire  
(Source: Sané survey, 2018)

Questions	Response hypotheses
1) By what method do you proceed to evacuate rainwater?	Sweep the water... .. / dig an alley... .. / use buckets ..... / others .....
2) Does your neighborhood have a stormwater drainage system?	Yes No.....
3) Is your house flooded during the rainy season?	Yes No.....
4) If so, how do you dispose of the water?	Evacuation by sampling ..... / Emptying truck.... / Canal ..... / Embankment... / Laying stone... .. / Laying sandbags... .. / No solution... / Other....
5) Do you have a perception on the salubrity?	Yes No.....
6) If yes, which one?	..... .....
7) How do you view the quality of the	Fairly clean... .. / Clean... .. / Fairly dirty...

environment in your neighborhood?	/ Dirty.... / Very dirty...
8) At what period of the year did you see the resurgence of these diseases?	During the rainy season ..... / Dry season.....
9) If it is wintering, justify?	..... .....
10) Do you think that rainwater associated with wastewater justifies the resurgence of these hygienic diseases?	Yes..... / No.....
11) Does the municipality participate in the evacuation of wastewater in the neighborhood?	If yes, how? ..... If not, why? .....

The data was collected through a questionnaire and an interview guide throughout this research. These interviews are intended for public and private actors who are the people in charge of the issue of sanitation in the city. Indeed, these selected persons are managers or technical actors who are well equipped to provide us with the necessary information on the situation. The strategy or method used was the interview survey. In this phase, we worked with the municipal officials in charge of environmental issues, the head of the regional sanitation department, the head of the hygiene brigade, the officials of the NGO PACTE, and the members of the neighbourhood councils in charge of environmental management.

Various data were collected from households and different administrative structures in order to better understand the conditions of wastewater management in the city of Ziguinchor. These data are of an infrastructural, cartographic, socio-economic and cultural nature. The field observation was also very useful, as it allowed us to observe the different practices of households regarding the collection and evacuation strategies of domestic wastewater.

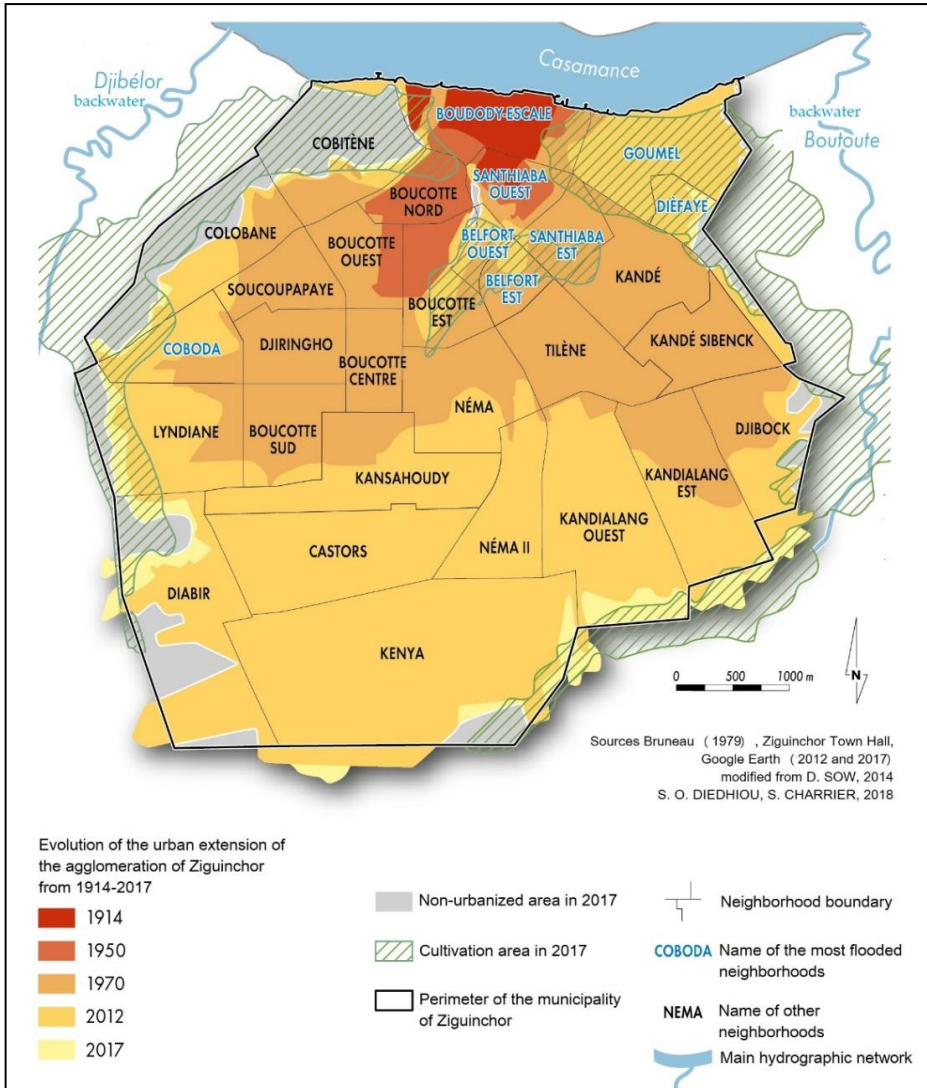
## **RESULTS AND DISCUSSION**

### **The problem of flooding in Ziguinchor**

The natural factors of the floods in Ziguinchor

Since 2009, Senegal has been experiencing an exceptional flooding situation. Dakar, Ziguinchor and several towns in the interior have experienced this phenomenon, which is linked to climate change on the one hand, and to the lack of sanitation infrastructure in urban centers on the other. Located in the south of Senegal, in a hot and particularly humid sub-Guinean climate, the commune of Ziguinchor has a seven-month dry season (November to May) and a five-month rainy season (June to October). In terms of rainfall, it is characterized by abundant rainfall varying between 1,000 and 2,000 mm for 80 to 100 days of rain. The highest rainfall was 2,006.5 mm for 104 rainy days in the 2020 winter season.

The number of rainy days per year fluctuates with an annual average of 83 days. Such quantities of rain received on a marshy substratum that characterizes the above-mentioned neighbourhoods, aggravated by the lack of drainage infrastructure for run-off water, partly explain the sanitation problems experienced by the commune. In the neighbourhoods of Boudody, Lindiane, Goumel and Belfort, for example, the heavy rains of 5 August 2020 affected secondary roads and houses, with people living under water even in their privacy, with a lot of damage.



**Figure 2.** Spatialization of flood-prone areas in relation to the expansion phases of the city of Ziguinchor from 1914 to 2017 (Source: Diédhiou, 2021)

Moreover, the town is built on a basin bordered to the north by the Casamance River, to the south by the commune of Niaguis, and to the west and east by the Djibélór and Boutoute backwaters, which constitute obstacles to the spatial extension of the town to the east and west. The physical-geographical characteristics of the site thus constitute a determining factor in understanding the manifestation of floods during the rainy season. The analysis in figure 1 shows that a large part of the districts of the municipality is exposed to flooding, especially the districts adjacent to the original core of the city. The neighbourhoods where vulnerability to flooding is most pronounced are those of Goumel, Santhiaba, Belfort, Diefaye and Boudody-Escale. The common denominator of these neighbourhoods is the very low topography, the sub-floor

nature of the water table and the presence of hydromorphic soils, i.e. more or less clayey. In detail, the districts of Boudody-Escale, Santhiaba, Belfort and Goumel are among the areas where the situation is most worrying. The topographical profile of the commune is characterized by a slope inclined towards the river (south-north). The physical characteristics of the site make the city of Ziguinchor vulnerable to flooding. The city of Ziguinchor is, therefore caught in a pincer movement and is enclosed by swamps that are vulnerable to flooding (Gomis, 2021). The low areas are characterized by the Ouljiennes terraces and recent fluvial-marine alluvium. Here we find grey soils and hydromorphic soils (mudflats). In these areas, the infiltration capacity of rainwater is very low or even zero. The water can remain in the low-lying areas for several days or even a large part of the year. The geological cross-section provides a better understanding of the flooding process of the districts in the city in relation to the topography. When it rains, the water converges on the depressions through the water drainage channels and flows into the Casamance River located to the north of the city. The relative steepness of the slope accelerates the runoff of rainwater into the depressed areas currently occupied by human settlements. As the water table is sub-surface in these areas, infiltration saturates the soil depending on the rainy season. This saturation of the soil and the impermeability of the surface (which reinforces runoff because of the high rate of cementing) quickly causes water to stagnate in depressed areas and flood the living quarters. This situation is aggravated by the existence of an undersized and poorly maintained water drainage system that is often clogged with rubbish and sand.

During these last decades, the commune of Ziguinchor knew a very important demographic evolution influenced by a significant arrival of populations of the rural areas of the region and Guinea Bissau. The increase in buildings has been particularly spectacular in Ziguinchor from independence to the present day. It results in the densification of buildings in agricultural areas and buildings constructed in new urban areas (Figure 2). Between 1976 and 2017, the population increased threefold, i.e. an annual growth rate of 4.4%. This rapid evolution of the city's population is at the origin of an unprecedented urban sprawl leading to an anarchic and uncontrolled occupation of certain spaces located on the periphery of the city. Indeed, districts like Kénia and Kandialang- East are located in these depressions or at the level of sites that were reserved for agricultural activities (Gomis et al., 2019; Sané, 2018; Sané et al., 2019; Gomis, 2021). The urbanization of the city of Ziguinchor took place in four phases. The first took place during the colonial period, the second occurs after independence more particularly during the crisis in the rural world, the third around the 1980s following the start of the politico-armed crisis in Casamance and the fourth which corresponds in the 2000s after the creation of basic infrastructure in the municipality.

#### Inadequate sewage system

The city of Ziguinchor, which is mainly built on a low-lying site, has been living with flooding for several years, the negative impacts of which are clearly visible, especially in the low-lying areas (Le quotidien, 2020). Every rainy season, there is a series of damages to infrastructure and housing, often resulting in the need to temporarily relocate people. The lack of means at the communal level is reflected in the absence of suitable infrastructure for the management of



rainwater and of real urban planning and development policies. Flooding caused by stagnant rainwater blocks access to certain neighbourhoods and concessions during and after the rain, for hours, days or even weeks. Communication routes in these neighbourhoods become impassable because of stagnant water with foul odours, which cause a real public health problem. The consequences of the floods are noted even in the privacy of the population. In the districts of Boudody, Lindiane, Goumel and Belfort, for example, the heavy rains of 5 August 2020 affected secondary roads and houses, with people living under water in their homes, causing a lot of damage (Figure 3).

The town of Ziguinchor, which is mainly built on a low-altitude site, has been experiencing flooding for several years, the negative impacts of which are clearly visible, particularly in low-altitude areas (Le quotidien, 2020). Each rainy season there is a series of damage to infrastructure and housing, often resulting in the need to temporarily relocate people. The lack of resources at the municipal level results in the absence of infrastructure adapted to the management of rainwater and of really urban planning and development policies. Flooding caused by stagnant rainwater blocks access to certain neighborhoods and concessions during and after the rain, for hours, days or even weeks. Communication routes in these neighborhoods become impassable because of stagnant water with foul odors, which poses a real public health problem. The consequences of the floods are seen even in the privacy of the population. In the districts of Boudody, Lindiane, Goumel and Belfort, for example, the heavy rains of August 5, 2020 affected secondary roads and houses, with people living underwater in their houses, causing extensive damage (Figure 3).

The problem of stagnant or uncontrolled runoff of rainwater is a serious one in Ziguinchor. Every year, during the winter season, several areas of the city of Ziguinchor are completely flooded. This situation exposes all the shortcomings of the sewage system. However, with Law No. 2009-24 of July 8, 2009 on the sanitation code, the State has placed particular emphasis on stormwater sanitation, with the definition of a single and harmonized sanitation code. As a result, rainwater drainage networks have been built in several urban centres to improve the living environment of the population and cover their sanitation needs. This is particularly the case in Ziguinchor which is a town that has no sewer system at all. There is only one storm water drainage network with three large storm water channels, to which are added a few secondary sewers connected to it. However, only neighbourhoods such as Escale, Boudody and Boucotte have open channels, but these are much degraded and often inoperable, and constitute wastewater and domestic waste spills. Due to the high runoff and the dilapidated state of the roads, which are gullied by rainwater overflowing the canals, several districts of the city of Ziguinchor are flooded or even exposed to the risk of flooding during the winter months. This is the case in Belfort, Goumel, Djibock, Coboda, Colobane, Santhiaba, Escale, Boudody.

This situation is also the result of the lack of an efficient sanitation, collection and disposal service for household waste. This is noted in the outlying districts with the presence of a poor sanitation policy. Thus, the absence of such a system, particularly in these neighbourhoods, is reflected in the unhealthy urban environment. As a result, the street and even the drains become receptacles for solid and liquid waste. And the observation is that every time the sky opens its floodgates, a good part of the rainwater floods the city, instead of ending up in its outlet.



**Figure 3.** Flooded neighbourhoods in Boudody, Lindiane, Goumel and Belfort  
(Source: Gomis, 2021)

#### Neighbourhoods located on rice-growing sites

It is true that all these neighborhoods located in flood-prone areas and which live permanently in the water during the rainy season, mainly housed agricultural activities in the past. Several factors explain the very high level of exposure to flooding in neighborhoods such as Goumel, Santhiaba, Boudody, Belfort, Djefaye, Djibock, Kandé (which are non-aedificandi areas). We can cite among others: urban dynamics, laxity and bad political strategies in terms of sanitation, the absence of an effective sanitation system, site constraints in Ziguinchor and the return of the rains. Thus, in each winter season, the rainwater from these districts flows into a very degraded natural canal which crosses the city; a canal invaded by wastewater at various places discharged into the stormwater network and which creates serious unsanitary problems (Le quotidien, 2020). With a population of nearly 205,294 inhabitants (ANSD, 2014), the city of Ziguinchor has neither a functional wastewater treatment network nor an effective stormwater management strategy. Failures combined with popular practices and behaviors which often result, thanks to the spatial dynamics of the city, in the occupation by the communities of non-aedificandi areas and where the lack of adequate sanitation infrastructure affects this the most deprived and underprivileged layers and threaten their living environment.

The occupation of these areas, formerly naturally inundated, poses the problem of floods which disrupt the socio-environmental life of the population. Poorly planned or controlled urbanization can increase the risk of flooding due to inappropriate changes in land use. The strong land pressure encouraged by

demographic growth thus leads to a lack of control over the spatial dynamics of the city. One of the important aspects to remember in this context is the dysfunctional use of space (Figure 4). The habitat is not welded in some places where the land under construction or not built becomes areas where water stagnates part or all of the year. These flooded areas increase the risks to health, safety and mobility. All these elements increase the city's vulnerability to flooding phenomena.



**Figure 4.** Peri-urban agriculture in Ziguinchor (cohabitation of houses with rice-growing plots) in the Lyndiane district  
(Source: Gomis, 2021)

The negative impacts of flooding in the municipality are exacerbated by the failures of the development of the municipal area, with in particular an anarchic urbanization characterized by an irregular installation of the most disadvantaged populations of the non-aedificandi areas, in particular in the areas low, and the ineffectiveness of the flood management system, particularly the dilapidated stormwater drainage network where it exists. This situation contributes to the multiplication of risks which make vulnerable populations located in areas with low topography.

The Korenthal, the main stormwater drainage channel in poor condition

The Korenthal is one of the oldest collectors in the city of Ziguinchor. It was erected in 1996 in the municipality of Ziguinchor with AGETP and municipal funding. It plays a very important role in stormwater drainage. It begins in the northwest of the Boucotte Est district at street level and successively crosses Belfort-Ouest, Santhiaba-Ouest and Boucotte Nord over a total length of approximately 2,630 m. Currently, it is degraded in its downstream part. Over much of the canal, the walls have subsided either due to erosion or human action. The canal is used by the populations as a dumping ground for solid waste of all kinds, in particular the traders of the Saint Maur des Fossés market. In addition, it is also used as a wastewater outlet, sometimes even by direct connection to local residents' toilets, as on the entire section between the Saint Maur des ditches market and the old IPRES. It is also very silted up especially in its downstream part after the bridge located on the road to Cape Town. The sand heights in the channel can reach in places more than 80% of the total height. This silting up comes from various origins but to a large extent it comes from the runoff from the sand streets towards the canal. During the rainy season, the canal overflows from its channel and participates in the

flooding of surrounding neighborhoods such as Belfort. This situation is aggravated by the existence of an undersized and poorly maintained water drainage system often clogged with garbage and sand (Figure 5).



**Figure 5.** Wastewater and rainwater drainage channels blocked by rubbish on boulevard 54, Tilène, Corentas and Escale in Ziguinchor  
(Source: Gomis, 2021)

In several districts (such as Belfort, Boudody, Coboda.), wintering rhymes with the plight of the populations. Symbol of the failures of the sanitation system, Belfort is a district which adjoins the Boulevard des 54 M and which is bordered by a poorly maintained canal that serves as a spillway for all kinds of garbage. This canal also crosses the Boucotte and Korenthas districts (Gomis, 2021). With each rainy season, the daily life of the populations is combined in Belfort with despair, anger, bitterness and helplessness. In addition, due to the impassability of the access routes, the mobility of populations is always compromised; and many houses are constantly inundated. It often happens that water floods the bedrooms and living rooms of many families who will almost lose their furniture, food and other everyday items. Added to this is the outbreak of mosquitoes which expose populations, especially children, to malaria, diarrheal diseases, and skin diseases so frequent during the winter in Ziguinchor.

This dramatic situation is daily in winter. In addition, it highlights the difficulties of household waste management and the failures of the sanitation system. These failures are also manifested by the piles of garbage everywhere and the discharge of water of all kinds into the sewers. Ziguinchor, with an average of 1,500 mm of rain per year, suffers from a notable lack of rainwater systems (Gomis, 2021). For many of the citizens we met, it is urgent to improve the level of sanitation in the various districts of the city; solve environmental problems caused by the discharge of untreated wastewater near concessions; and reduce flooding caused by stagnation or uncontrolled runoff of rainwater.

### **Resilience and adaptation strategies to flooding in Ziguinchor**

Urban populations in West Africa are increasingly vulnerable to flooding. In Ziguinchor, in the immediate outskirts of the city in particular, the repetition of these phenomena has led the populations to adopt multiple responses to the risks and consequences that may result from them. Although insufficient, these responses have implications for household income.

Sketches of solutions for the population that are far from ending their ordeal

Coping strategies are implemented before, during and after floods to preserve household and community assets. The affected populations react spontaneously with precarious means. These include, among other things, the use of bricks, sandbags and tree trunks, the making of backfill (with sand, rubble, waste), water drainage with rudimentary means (buckets and basins), drainage, pumping, laying of precarious pipelines (digging trenches or using PVC pipes) and protective dikes and the development of access to houses to mitigate the risks. The rainwater drainage methods used by the households in our sample are therefore traditional types and are temporary (Table 1).

**Table 2.** Evacuation mode in case of flooding  
(Source: Sané survey, 2018)

Households	Drainage of water by means of a bucket	Backfilling the house	Use of gravel	Sandbagging	No solution	No answer	Total
Number	48	29	37	19	59	193	385
Frequency	12,5	7,5	9,6	4,9	15,3	50,1	100

The survey results show that the main solution adopted in the event of flooding is to collect water (bucket or basin) with a frequency of 12.5% of the 192 households confronted with the flooding phenomenon. This was followed by the 9.6% of flooded households who filled their houses with gravel or shells. This gravel sucks up standing water and mitigates infiltration when the ground is at some point saturated. These households sometimes buy the gravel and transport it with carts. Embankment is the third solution adopted by flooded households (7.5%). Their techniques consist of building an embankment to prevent water from overflowing into their plots. Sandbagging accounts for 4.9%. Some households are forced to stay under water because they have no solution (15.3%) to deal with it. However, it should be pointed out that these techniques

are non-structural in that they do not put an end to the flooding problem for good. They only provide relief to the population.

The interventions of the populations on the dwellings concern the modification of the pits and the toilets, the construction in height, the work on the roofs. In addition, there are other strategies such as paving, flooring, raising walls, sealing cracks and changing the slope of roofs. The relocation of some household members is also part of these adaptation strategies: in 2011, a third of households in the districts of Coboda, Néma II, Lyndiane or Soucoupapaye had at least one member who moved due to flooding.

Outlines of solutions from the authorities that are far from curbing the plight of the population

The Senegalese state is making many efforts to solve the problem of the lack of public sanitation infrastructure in Senegalese cities. However, the inadequacy of this infrastructure in the city of Ziguinchor remains a major difficulty facing the authorities and the urban population. Given the urgency of the situation and the environmental and socio-economic challenges, it has become imperative for the State to pay much more attention to the city's sanitation problems. In 2010, the State allocated 6860205.78 euros from the African Development Bank (ADB) to the city for the implementation of a sanitation master plan. Answers to the problem of sanitation in the city will allow the construction of 22 km of wastewater networks, 1863 sewer connections, a treatment plant with a capacity of 3900 m<sup>3</sup> per day. And according to the communications officer of the town hall of Ziguinchor, the city is, he said, being equipped with a faecal sludge treatment and recovery unit; a project now over 95% completed. This is in parallel with the All to the Sewer Project for wastewater financed by the AfDB and AFD (French Agency for Development) and executed by ONAS for the benefit of the municipality of Ziguinchor (Le quotidien, 2020).

This state of affairs requires structural investments and pipelines to drain water into the river. To achieve this, the town hall of Ziguinchor relies on decentralized cooperation, in particular with the Euro-Mediterranean agglomeration communities and the Norman agglomeration community in France, to support the strengthening of the stormwater drainage network. Despite the many efforts of the Town Hall, land constraints and also those related to changes in mentality and behavior of Senegalese in relation to the management of their environment, constitute enormous weaknesses in relation to the sanitation policy. If we estimate in linear meters, Ziguinchor is much better endowed with pipelines than many large local authorities in Senegal. But there is the behavior of the population, who dump any type of garbage anywhere in the city.

In the city of Ziguinchor, the production of garbage is around 46,800 tonnes in 2020 (Gomis, 2021). However, there is no modern infrastructure (landfill or treatment center for the sustainable management of solid waste. urban), the existing system consists of collecting garbage and forwarding it to the final landfill of Enamport. Trucks, tricycles and carts are set up to collect garbage from transit points and take it to landfill. At the municipal level, the town hall manages the pick-up and collection system with a concessionaire (the Robotech Company), based in Dakar. The collection system consists of picking up garbage in markets and collection points, illegal garbage dumps in the thirty-six districts of the municipality of Ziguinchor due to two rotations per day and

forwarding them to the final landfill. The maintenance of the landfill and the garbage which is sent to the final landfill is the responsibility of the municipality of Enampont which houses the landfill. Garbage collection in Ziguinchor by the service provider Robotech is experiencing a number of logistical difficulties. The company has a dilapidated fleet of vehicles including three trucks, two tampers and a mechanical shovel that often breaks down. Faced with this situation, the city is very often inundated with garbage and the populations often deposit their garbage everywhere in the city. Despite the information / sensitization campaign of the populations regarding the correct disposal of garbage, the situation persists.

The municipal institution often carries out a vast operation of cleaning the gutters at certain strategic sites such as Colobane, Soucoupapaye, Boucotte, Santhiaba, Belfort, Nema II, Kandialang checkpoint and at the Jules Bocandé stadium. Despite the cleaning work carried out by the town hall each year before the fall of the first rains in Ziguinchor, these practices of the populations living in the open canals block the evacuation of rainwater. Today, it is obvious that the management of the problems linked to the floods is not yet effective in several districts of the city of Ziguinchor. Even though many efforts are being made by the State, the town hall and their partners, the risks of flooding are still very real, especially with the return of the rains. Pending the establishment of an effective system for the management of rainwater, it is incumbent on the competent authorities to sensitize the populations on a certain number of practices and behaviors assimilated to environmental damage and which destroy any development effort.

The rubbish dumped in the open canals and the sand that fills them no longer allows rainwater to drain away. It often ends up in houses or in the arteries of neighbourhoods, most of which have not yet benefited from the paving programme and/or are in an advanced state of degradation. Added to this is the pollution of the water table in the low-lying areas, directly exposed to the infiltration of toxic elements from household waste. This causes public health problems in these areas, as most people do not have a drinking water connection to the SEN'EAU and use wells for their domestic needs. As the slope is inclined towards the lower points following the channels and the natural water paths, runoff remains significant. However, at this level, the water table is outcropping, so when infiltration saturates the soil, the water rises.

The wait-and-see attitude and lax reaction of the municipal authorities to the recurrence of floods has led the populations of certain flooded neighbourhoods to demonstrate their discontent. During the winter season, heavy rains are permanently recorded in the city, making communication arteries impassable and access to certain districts difficult. The drainage channels are overflowing. And the sanitation work underway as part of the PROMOVILLE programme is aggravating the problem. Several neighbourhoods in the city, notably Belfort, Boudody, Grand Dakar, Lyndiane, Korentas, Santhiaba and Boucotte are flooded.

The recurrent floods in cities like Ziguinchor reveal the dysfunctions and inconsistencies of several decades of public policies in terms of development, occupation of urban space and sanitation in the city. Faced with the urgent need to find solutions to the increasingly dangerous and costly floods, the State of Senegal and the municipal authorities have set up an intervention and support system for the victims of this disaster. In Ziguinchor, the town hall is supported by the National Group of Firefighters, which is responsible for flood management

under the control of the Governor of the Region. The firefighters come in to help and fight against the phenomenon which exceeds the populations. For the most affected layers, food aid and materials are often distributed immediately to meet the needs of the victims. It is in this logic that a large batch of equipment was deployed in July 2011, August 2013, and August 2017 on the most affected sites in the municipality for the evacuation of stagnant water in the streets and primary schools.

The strategic orientations to reduce the risks of flooding in the city of Ziguinchor must seek the right balance between infrastructural and non-infrastructural measures with certain cross-cutting measures and plan their implementation and evolution over time according to available resources and those that can be mobilized (Gomis et al., 2019; 9, Sall and Sy, 2015, Sané et al., 2019; Gomis, 2021).

- Infrastructure measures require significant investment and will only bear fruit in the medium and long term. Their planning must be done in coherence with an urban restructuring plan which should cover all peri-urban areas.

- Non-infrastructural measures allow a shift from a defensive approach against calamities to a risk management approach. It is recommended to favor these measures while planning the protection and drainage works. These are mainly: - Emphasis on flood prevention through urban planning and management; - Strengthen the preparation framework; - Set up a forecasting and early warning system; - Promote resilience for behavioral changes and resilience; - Integrate disaster risk reduction (DRR) into all communal development programs; - Establish partnerships and networks on DRR.

- The institutional aspects contributing to flood control in the city of Ziguinchor concern (i) the clarification of the institutional, regulatory and financial framework, and (ii) the capacity building of the actors concerned by the implementation of the strategy.

The development of a flood risk reduction strategy in the city of Ziguinchor is therefore a process leading to a prioritization of these measures and above all to find the right mix between infrastructural and non-infrastructural measures and to plan evolution over time. This balance must be adapted to the socioeconomic context of the city of Ziguinchor in particular and Senegal in general.

## **Discussions**

The objective of this study was to characterize the problem of rainwater management in the city of Ziguinchor. The results obtained attest to a real problem of sanitation of rainwater managed in precarious conditions due to the lack of infrastructure and water management methods used by households. The infrastructural problem is a factor in the poor management of rainwater in Ziguinchor, while rainwater drainage practices do not protect the living environment of the populations. In the city of Ziguinchor, most of the sanitation infrastructures relate to gutters and structures set up for the evacuation of rainwater. Given their fragility, households have the heavy burden of managing the water that stagnates in their homes according to their financial means. However, as for the Senegalese state, there is a lack of financial resources at the household level.

According to the results obtained, in Ziguinchor, wastewater is managed in precarious conditions due to the infrastructural problem and the drainage



methods used by households. These results confirm those obtained by Ngnikam et al. (Ngnikam et al., 2007) when they state that the situation in African urban areas is one of precarious sanitation. The example of the informal settlements in Yaoundé and the coastal areas subject to flooding in Douala is a good illustration.

The few existing public sanitation infrastructures, namely the gutters, are insufficient and unevenly distributed over the urban territory. And even the existing network of drains for the evacuation of rainwater is very limited. It is only found in a few areas of the city centre, to the detriment of the peripheral areas and the informal settlements. These results confirm those obtained by Soro and Vei (2017), when they state that: 'the under-equipment is general in the legally evolving neighbourhoods, and the infrastructures or collective equipment are non-existent in the housing neighbourhoods not allocated by the administration'.

These results confirm those obtained by Faye (2014) in the municipality of Ziguinchor when he states that the situation is one of precarious sanitation. The example of a few spontaneous neighbourhoods in Ziguinchor (Nema 2 and Coboda), where each family has only one infrastructure, most of which does not comply with standards, is also a good illustration (ANSD, 2014). Kafando (2004) follows the same logic when he says that "In Ouagadougou wastewater is managed in difficult conditions". The practice for the majority of households (nearly 90%) is to throw wastewater into the street, into the gutters or onto the ground of their concessions", (Kafando, 2004). "In such situations, one quickly ends up with a poor state of hygiene and permanent contamination of the environment" (Nkenku, 2005). These authors deplore the sanitation conditions in certain towns in the West African sub-region. In Ziguinchor, as in these cities, autonomous sanitation predominates, and the wastewater management methods used by households are generally inappropriate (Gomis et al., 2019; Sané, 2018; Gomis and Thior, 2020; Sané et al., 2019).

These precarious wastewater collection and evacuation infrastructures and strategies are adopted by households given the deficit in public sanitation infrastructures (Soro and Vei, 2017). Indeed, in Ziguinchor, there is no sewage system capable of ensuring the collection, evacuation and treatment of wastewater (Sané, 2018). The inadequacy of public sanitation infrastructure exists because of limited financial resources at the level of urban authorities and especially the state. This assertion is supported by Vei (2012) who notes that 'the lack of financial means at the level of the Ivorian state and the communes, as well as the lack of technical capacity have been accentuated by the socio-political crisis since 2002'. This has led to excessively problems in the urban environment... (Sall and Sy, 2015). In most inland towns, there is no infrastructure for domestic wastewater treatment, which poses a real environmental problem. All of these difficulties are the main factors behind the poor management of wastewater in Ziguinchor (Gomis et al., 2019). In this city, where the issue of wastewater management is a major concern for both urban authorities and households (Sané, 2018), new strategies are needed to achieve adequate wastewater management and protect the population's living environment from wastewater. These strategies will have to be adopted at both state and household levels, with an emphasis on the management methods used by households.

The problems of drainage of rainwater in urban areas must be studied from a particular angle, hence the need to develop collective resilience actions.

Since they are concerns for the population questioned, a search for alternative solutions to the issue of recurrent flooding in the city must be a priority for the actors in charge of the component. In Ziguinchor, we noted a handful of initiatives that were certainly developed, but their follow-up had hitherto been a major constraint. The issue of land legislation needs to be better taken into account by town planning departments and local authorities. On this point, we share the suggestions of Sy et al. (2012) which consist in enforcing standards and regulations in terms of town planning, evicting inhabitants occupying flood-prone sites, developing them and cleaning them up. This approach seems to be the best suited to finally put an end to these problems of occupancy of beds and waterways. Of course, it will be a very complex operation, including the social realities of our African cities, but the authority remains the primary actor and decision-maker in regional planning.

Regarding drainage works, even if they are also undersized, maintenance must be carried out by the authorities. Also, these structures and their downstream maintenance are not the only alternatives to flood control in these neighborhoods. However, we suggest that quite simply that there is a good mastery of stormwater by initiating additional techniques to fill the deficit of the drainage network, especially since Dasylyva et al. (Dasylyva et al., 2002) the suggested in Dakar. For them, these works are less expensive and only intended for rainwater and would serve as a back-up and not as a substitute for current drainage networks. Obviously if these structures are well constructed, they will undoubtedly be of great use in the city. This is all the more true as experiences have shown that the use of alternative technologies to storm sewerage networks does not increase the costs of servicing the equipped area. In addition, they contribute to a very significant reduction in the costs of structuring sanitation equipment (Deutsch, 2003).

The search for solutions to sanitation problems must be seen from several angles, in this dispute of the rapid evolution of the city's population, which is at the origin of an unprecedented urban sprawl and an anarchic and uncontrolled occupation of certain spaces located on the outskirts of the city (Diedhiou et al., 2020; Sakho et al., 2016; Nouaceur, 2020). Their impacts are still inestimable in the city, and it is necessary to involve the population to fight against the consequences. The work starts with a change in the behaviour of the population, first of all, from the discharge of wastewater into the drainage system. Certainly, some neighbourhoods are not well served by drainage infrastructure, but it is important not to obstruct it with rubbish and so on. This work will involve local authorities, decentralised state services, the population and NGOs in order to provide a significant response to the issue of sanitation and to ensure the well-being of the population and protect the living environment of the population (Sané et al., 2019).

The perverse negative impacts of climate change in the countries of sub-Saharan Africa require appropriate measures. However, populations and productive systems in many developing countries are highly dependent on natural resources and often have relatively limited adaptive capacity. The list of biophysical and socio-economic impacts which worsen the current related problems is long, in particular the floods which are increasingly recurrent and which even affect urban planning. In West Africa, the phenomenon is felt with varying degrees of intensity (Tchindjang et al., 2019; Abroulaye et al., 2015; Maloba Makanga, 2017). Despite the enormous sums swallowed up, the floods

seem to defy the cities, the causes being to be found in the population growth and the unprecedented urbanization that these cities are experiencing. All this is combined with the rural exodus, industrialization, the anarchic occupation of hydro systems by precarious dwellings and finally the non-respect or non-application of the existing urban master plan (Tchindjang et al., 2019).

To achieve a real urban planning policy in Senegal, public decision-makers should consider more evaluation in the development of public policies in a holistic manner. The call for more evaluation is part of an environment that marks the transition from the classic system of government to governance to better reflect the interaction of several actors and the integration of several parameters in the search for performance of public action.

This study shows the role of physical (oro-hydrography, rainfall.) and human (anarchic land use) factors in the occurrence of floods in Ziguinchor. We have seen, for example, that the urban extension of Ziguinchor between 1984 and 2017 was carried out primarily on the major bed of the river and its backwaters made up of gently sloping land and numerous formations, swamps, thus exposing various socioeconomic issues to the risk of flooding. Several factors limit the use of traditional approaches to assessing flood factor in the study area. The first limitation is caused by the inclusion of individual vulnerability (perception, representation of risk) in the analysis. We are aware of the limitation imposed by this specific case study in the goal of generalization on a larger scale, however we believe that this research may provide an interesting database for future research on flooding.

Proper management of sanitation requires sustainable urban development. Planning urban development for universal access to essential services is a categorical imperative for a country like Senegal. Indeed, providing quality essential services that guarantee a decent living environment for the population requires the adoption of both a global planning of the territory and a differentiated planning according to the districts. In the interests of equity, precarious neighbourhoods must be a priority target for public policies on access to basic services in Senegal. As a key actor who makes political choices that affect the country's future, the Senegalese public decision-maker should undertake actions that are un-derpinned by consensual decisions articulated through a decision-making mechanism. The decision-making mechanism should be understood here as a process involving a plurality of actors with different preferences, interests and identities. This logic refers to the good governance that this work promotes. Good governance pursues an ideal of dignity and progress. It contributes to the satisfaction of the vital needs of the population. It contributes to the promotion and well-being of men, women and children, with the aim of ensuring education, work, care and social protection for all. It enables a fair distribution of national wealth. It allows initiative to develop.

Methodologically, this work was based on various data obtained from information collected from households and administrative structures. The main difficulty lies in the organisation and processing of the mass of information obtained during the data collection. The management of rainwater is one of the major challenges of the city today. The question demands all the more attention as the sum of the constraints weighing on the Third World city continues to grow. The sustainable management of rainwater therefore requires a global reflection that takes into account all the problems, constraints and challenges of the area considered.

## CONCLUSIONS

With this research work, we tried to approach in an integrated way the problem of rainwater in the management of space, in the case of the city of Ziguinchor. With this work, we have tried to bring elements of knowledge and answer in a broader perspective. The systemic analysis made it possible to highlight the disruptive effects of the faulty management of space on the urban rainwater management system. This finding of the deficiency calls into question urban policy in general.

Apart from this difficulty, this work has made it possible to present relevant and usable results in the context of urban sanitation in Senegal, particularly in Ziguinchor. In-deed, this study made it possible to analyse the conditions of rainwater management in the city of Ziguinchor. At the end of the study, it was found that wastewater in the city of Ziguinchor is administered in precarious conditions, hence the presence of wastewater in the living environment of the city's populations. In reality, the way wastewater is disposed of in Ziguinchor does not meet the fundamental objectives of individual sanitation, namely the elimination of all causes of environmental pollution and the protection of the population against health risks. On the contrary, this type of sanitation increases the damage to the environment and exposes the population to diseases linked to the dissemination of wastewater. The management of run-off water in Ziguinchor is a concern for the population. The high rainfall levels, combined with the area's sensitivity to infiltration and the problem of drainage, have increased the phenomenon. To cope with this problem, some households are organising themselves individually to find so-called non-structural solutions, such as backfilling, placing sandbags and stones or even building walls and ledges around their houses. These local initiatives are deployed by the populations in order to better cope with the constraints. Moreover, the indifference of local authorities to this problem justifies the incoherence and obsolete nature of environmental management policies in our cities.

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