THE PROBLEM OF INTEGRATED FLOOD MANAGEMENT IN A VULNERABLE TOWN IN SENEGAL: THE CASE OF KAFFRINE

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Abstract—This paper analyses a typical model of an urban flood management system in Senegal. The aim is to assess the achievements and shortcomings of this system through the case study of the city of Kaffrine in order to develop an integrated urban flood management system.

The Kaffrine flood management system operates along two main lines: a preparatory phase for disaster management and actual crisis management during floods. However, the floods of 2013 and 2016, which were more significant in terms of scale and damage then all previous ones, have shown the limits of this management system.

An analysis of the way the system works shows that it has many shortcomings, including limited knowledge of the real causes of the floods by most actors, the non-involvement of all key players, inadequate coordination of interventions and lack of means for maintaining and building appropriate infrastructure.

Index Terms—urban floods, Kaffrine (Senegal), crisis management, integrated water resources management, forecasting system.

1 Introduction

In the context of urban flood management, at a time when developed countries are very advanced in the research and adoption of techniques ranging from forecasting to crisis management, developing countries such as Senegal are lagging behind. Yet flood risk [1] has become the most important natural hazard in Senegal's cities. While most cities have been the subject of studies [2], [3], [4], [5], this is not the case of the city of Kaffrine where floods cause more damage than fire. This "collective" risk [6] has become recurrent since 2003.

Located in the Sine-Saloum valley [7], the city of Kaffrine is faced with the problem of runoff water during the rainy season. Most of the rainwater runoff comes from the south-eastern periphery of the city and flows northwards where the Saloum river bed is located. However, urban development such as the national road No. 1 (RN1) and especially the Dakar-Niger railway [8] are structural elements that modify the waterways [9]. Their directions are deviated and they flow southwards to invade the flood-prone districts. The situation is all the more serious as the city is not equipped with adequate hydraulic infrastructures for rainwater drainage.

Since the onset of the floods in the 2000s, the local authorities set up a flood management system around a Flood Control Committee (DFCC). However, the extent of the damage caused by the floods of 2010, 2013 and 2016, which have left their mark on the minds of the population, have shown the limits of the management system.

In order to find sustainable solutions to this persistent problem, a diagnostic study of the existing situation must necessarily be carried out to identify the flaws. The objective is to make a descriptive analysis of the way urban floods are managed in the town of Kaffrine in Senegal. We present the management of floods according to the vision of the actors in charge of this issue. And after a presentation of the study area, we will analyse the DFCC flood management system, the preparatory phase for crisis management, the management of the crisis itself and its flaws.

2 Materials and methods

The methods are based on three ain parts: the collection and analysis of information from surveys of the actors in charge of flood management in the town of Kaffrine and the exploitation of documents available (archives, reports, press...).

The survey guide consisted of 30 questions divided into 4

main parts: (1) the identity of the different actors or structures involved in flood management; (2) the types of intervention; (3) the evaluation of the means deployed and (4) the partnership links or collaboration between the actors.

2.1 The collection

The first stage of our investigation was to identify all the actors involved in the fight against flooding in the city. We started with the focal point in charge of crisis management at the departmental level (the prefecture) in general, and the city of Kaffrine (chief town) in particular. Starting with the prefecture, all other actors were identified through the questions in the fourth part of our interview guide. This part focused on the search for institutions and/or other actors with whom the respondents worked closely in the fight against flooding. Cross-checks made at the end of the surveys made it possible to obtain a complete list of the actors in charge of flood control in Kaffrine. They officially form the Flood Control Committee (DFCC).

2.2 The analysis

The collected information has been analysed by qualitative methods. If possible, data of different sources has been triangulated in order to obtain a solid database.

2.3 Field visits and observations

Field visits and observations are regularly made between 2017 and 2018 to supplement the information provided by DFCC members.

After a brief presentation of the study area, this article analyses the flood management system in terms of actors, preparedness, and crisis management and fault lines before concluding with a conclusion.

3 Results

3.1 Kaffrine: a city vulnerable to climate change

The town of Kaffrine is located in the centre of Senegal, more specifically in the Saloum Valley whose intermittent rivers flow through the Continental Terminal [10]. Kaffrine is a commune administratively circumscribed in 1960 on an area of 440 hectares with 4 districts including Escale, Peye, Mbamba, Kaffrine 2 (divide nowadays in Kaffrine 2 South and Kaffrine 2 North) [11]. Today, the city extends far beyond its perimeter including 8 new districts (Fig. 1) and counting a total population of 39.536 [12].

It is built at low altitudes area marked by the presence of ponds in the rainy season in its northern part, hence the nickname "city based in a basin" [11]. After each rainfall, runoff water stagnates in the city and its surroundings, which has become problematic because of urban development and densification. Due to the lack of appropriate hydraulic infrastructure and the construction of elevated roads and railways built perpendicular on the runoff direction. While the RN1 has been equipped with several water passage tubes, albeit poorly calibrated, the railway has almost none in the city centre. Consequently, runoff water regularly finds its way by breaking through, causing instant flooding of the neighborhood behind.

The town of Kaffrine has an ancient rainwater drainage network that only serves the central market. It consists of an underground pipeline network oriented towards the west of the city, initially without discharge infrastructure. During the floods of 2016, the municipal autorities had dug a retention basin at the outlets (still within city borders) in order to control the discharge and collect additionnaly the water pumped from flooded residential areas. Other small sections of open gutters are located alongside the RN1 since its rehabilitation in 2010. Not only is this drainage system insufficient and non-functional, but it does not take into account the natural water system.

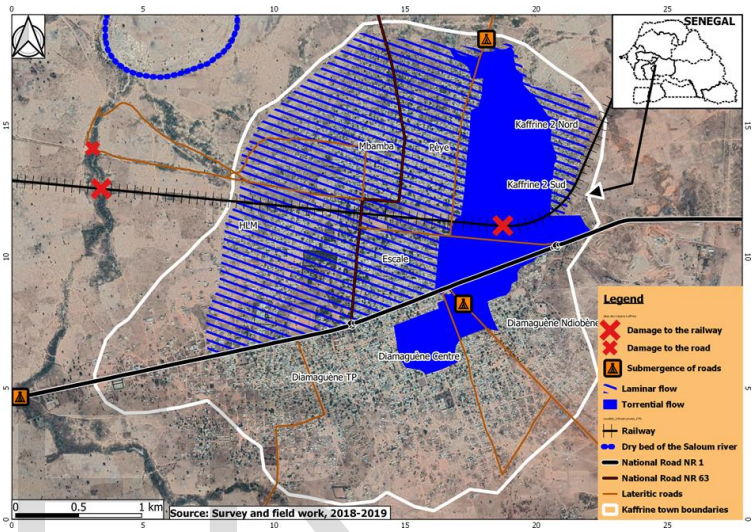

Fig. 1. Kaffrine flooded area in 2016

The storm water runoff that is causing the most problems for the city comes from the eastern part of the watershed. It flows downhill through a channel carved in the hardened laterite soil (PHOTO 1), towards the north-east of the city. The speed and strength of the flows seem to be important in view of the impacts on the railway infrastructure (PHOTO 2a. and b) and despite the actions undertaken to counteract them. The vulnerability of the railway track is undoubtedly due to the granular and unpaved nature of its base making it erodible [13]. It is also linked to the absence of flow crossing structures at critical stances and their undersizing, if they exist. The railway bed in the city had a nozzle but was closed in 1992 [13]. This closure was requested by the population of the two downstream neighbourhoods (Kaffrine 2 South and North) following the impacts of flows passing through the nozzle.

Photo 1: Nature of the soil in the drainage channel (where most of the runoff water comes from) on the outskirts of the town of Kaffrine.

a°)- Into Kaffrine town

b°)- On the north-western outskirts of the city

Photo 2: Water impact on the Dakar-Bamako railway (in 2016).

3.2 Analysis of the flood management system

A management system can be defined as the holistic set of actors and processes united in the management of a specific topic, in this case flooding.

3.2.1 Typology of actors and Kaffrine Flood Control Committee

There are several actors involved in flood management in Kaffrine (Fig. 3). They can be grouped into three main categories according to the modes of intervention for flood control: (1) coordination of operations, (2) safety of disaster victims and evacuation of stagnant water, (3) assistance or humanitarian aid.

The governance, the prefecture are in charge of coordinating all operations related to flood control. The safety of the disaster victims during the events is ensured by the services of the gendarmerie, the urban police of the fire brigade. The Fire Brigade Group is also responsible for evacuating stagnant water through the pumping operations that we will see in the pumping operation sub-section. Finally, the other technical and/or administrative services such as the town hall, the Hygiene service, the health district and the Red Cross are involved in various forms of assistance to disaster victims such as census, hygiene and health care. The World Vision has mainly played the role of humanitarian aid through the granting of financial resources for the purchase of emergency food and hygiene kits [14].

Most of them belong to the Departmental Committee for Flood Control in Kaffrine (DCFC). It was created by decree to rule on decision-making regarding flood management methods in the various localities of the department. The DCFC is composed of 17 members who are listed in the table below. It is chaired by the Prefect and the director of the CPSR provides the secretariat.

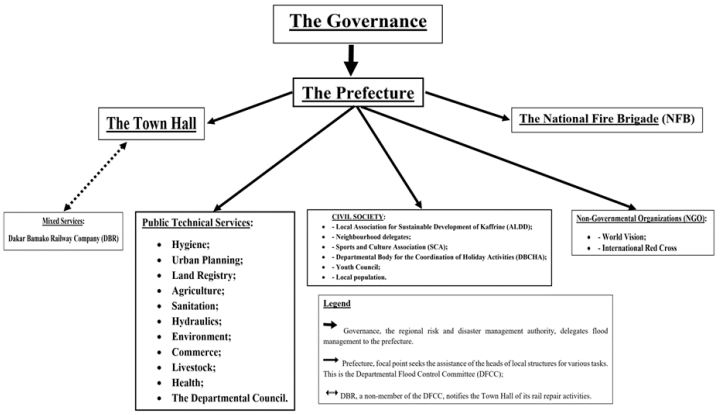

Fig. 2. Organizational chart of the actors involved in flood management in Kaffrine.

Table: Members of the Kaffrine Flood Management Committee

Members of the Departmental Committee for Flood Control	Post
The Prefect of the department or his representative	President
The Director of the Centre for Promotion and Social Reinsertion (CPSR)	Secretary
The Mayor or his representative	Member
The Commander of the Mixed Gendarmerie Brigade	Member
Kaffrine Urban Police Commissioner	Member
The District Chief Doctor	Member
The Head of the Departmental Service for Rural Development (DSRD)	Member
The Head of the Departmental Department of Hydraulics	Member
The departmental Manager of SENELEC	Member
The departmental Manager of the SDE	Member
The World Vision project representative	Member
SONATEL departmental representative	Member
The head of the departmental hygiene service	Member
The head of the departmental community development service	Member
The head of the Water and Forests sector	Member
Two representatives of the Local Association for Sustainable Development (ALDD) in the Diamaguène district	Member
Neighborhood delegates	Member

3.2.2 The preparatory phase

3.2.2.1 Pre-rain season meetings

Various special pre-wintering meetings dealing with flooding issues are organized annually in the town of Kaffrine. These are the meetings of the Regional Development Commission (RDC) and the Departmental Development Commission (DDC) which are chaired respectively by the Regional Governor and the Departmental Prefect of Kaffrine.

The RDC is a meeting organized by the Governor of the Kaf-

frine region. It brings together all the prefects and sub-prefects of the 4 departments (Kaffrine, Koungheul, Birkilane and Malem Hoddar) and some guests including representatives of the technical services of the regional capital (Kaffrine). It is a framework for regional consultation during which major guidelines and recommendations on the management of risks such as floods are taken. The RDC is also a meeting to take stock and exchange on the feedback from previous floods in terms of successes and shortcomings.

As for the DDC, it is the responsibility of the departmental prefects. They implement the guidelines and recommendations of the RDC at the level of their respective departments. In the town of Kaffrine, the DDC brings together all the actors of the DCFC.

These pre-wintering RDC and DDC are also an opportunity to define action plans for crisis management for the next rainy season. However, several local actors in the town of Kaffrine indicate that these meetings are irregular, as was the case in 2016, the year of the greatest flooding.

3.2.2.2 Existant drainage infrastructure and cleaning of gutters

The town of Kaffrine has an ancient rainwater drainage network that only serves the central market. It consists of an underground pipeline network oriented towards the west of the city, initially without discharge infrastructure. During the floods of 2016, the municipal autorities had dug a retention basin at the outlets (still within city borders) in order to control the discharge and collect additionnaly the water pumped from flooded residential areas. Other small sections of open gutters are located alongside the RN1 since its rehabilitation in 2010. Not only is this drainage system insufficient and non-functional, but it does not take into account the natural water system.

During the dry season, the gutters are progressively filled with sand, rubble and solid waste, mainly household refuse. At the approach of the rain season, the municipal autorities are in charge of the cleaning the drainage system in order to facilitate a good circulation and evacuation of rainwater. This operation is rather easy for the open gutters of the RN1, but much less so for the closed gutters of the central market. It requires more technical expertise. The municipal autorities is assisted by the National Sanitation Office of Sénégal (ONAS) for dredging.

3.2.3 Broadcasting programs

The prefecture and the municipal autorities carry out alert campaigns through radio broadcast to make the population of flood-prone areas aware of the measures to be taken during the rain season. Among these messages, one can essentially mention the search for temporary shelter, securing food and goods, staying away from retention infrastructure and large walls, etc...

3.3 The phase of flood crisis management

Crisis management is a matter of alerting and intervention by the emergency services and of coordination between these different services, the deployment of intervention means, communication capacities, etc. [15].

3.3.1.1 Evacuation and re-housing of disaster victims

The National Fire Brigade (NFB) is in charge of all evacuating operations. However, citizens often intervene equally to rescue people in danger. In the Kaffrine 2 neighbourhood for example, where water levels rose very quickly to almost 2m, young adults played a major role in rescuing people in danger before the BNSP arrived. The people most concerned by these evacuation efforts are children and the elderly, who experience difficulties escaping the force of the waters. Although the catastrophical extent of the floods in Kaffrine, uptill today the evacuation operations have always been suc-cessful. There are never casualties registered during this critical phase of the event.

There are three modes of relocation. Only few victims have the means to find temporary shelter by renting another dwelling until the end of the rain season. By far the most common option is moving in with close relatives, friends or acquaintances. Relocation in public schools, which is under the responsibility of the DCFC, is generally the last option. In 2016, only 30 families from more than 857 families affected by the floods were relocated in public schools. Luckily, the rain season coincides with the closure of classes for the summer holidays, which leaves them the time to settle down and save up money for the reconstruction of their houses.

3.3.1.2 Census and food distribution

The prefecture is responsible for the distribution of all receiven aid. To do so, the prefectural authorities set up by decree a commission for the census of disaster victims [16] [17]. The sub-units are directed and controlled by DCFC members. For this purpose, it uses the youth services of the Regional Youth Council and the volunteers of the Senegalese Red Cross section of Kaffrine. In 2016, in order to prevent possible irregularities, the prefecture set up, in addition to the census commissions, census validation and aid distribution commissions [17], [18], [19] (Order No. 163 /P.KAF; Kaffrine, 26 August 2016).

Aid comes from various sources and types is granted and/or actively collected by the DCFC. They come from the State, the commune, Non-Governmental Organizations (NGOs) and a few individuals of good will from civil society [18]. The most common type of aid is food assistance and hygiene products in the form of emergency hygiene kits consisting mainly of kettles, bleach, and soap and washing powder [14].

3.3.2 Retention basins and pumping

In Kaffrine, retention basins are simply dug into the earth (PHOTO 3), which is an old and still widespread fashion to regulate rainwater runoff [20]. The city has five retention basins, three in the Kaffrine neighbourhoods and two others on its northern periphery. There are two types of retention basins: those that collect overflows and automatic pumping water from flooded areas, and those that mitigate or dampen natural flows. However, this infrastructure does not adequately fulfil its function of regulating rainwater runoff. Their size is insufficient: they fill very quickly and most of them cannot collect all the runoff. In addition, they have a low infiltration capacity. Sadly, those basins have been the macabre setting of children drowning, because of the lack of securisation and sensibilisation. The authorities did installe barbed wire fences to prevent accidents to happen, but those safety devices are

quickly vandalized by individuals in search of iron.

Photo 3: Retention basins and overflow of pumped water from flooded areas

3.3.3 Damping retention basins

As measures to control runoff, the communal authorities dug a series of string retention ponds (PHOTO 4) south of the RN1 on the site of the former lateritic armourstone quarries. Downstream of this series of retention basins, a concrete protective dyke (PHOTO 4) was erected to encircle them.

Photo 4: Rainwater retention and drainage basins and concrete protection dam against runoff.

3.3.4 Pumping operations

The stagnant water from the various flooded sites is evacuated by automatic pumping by the fire brigade (PHOTO 5). Pumping is often carried out one or two days after the floods due to the uncontrolled time of occurrence of floods, which are generally sudden. Indeed, the first and most important reaction consist of rescuing the people in danger. The installation of the disposable pumping system preceeds the pumping operations themselves.

To illustrate these pumping operations, during the floods of 24 July 2016, a volume of 11925 m^3 was pumped from two densily populated sites using only two motor-driven pumps of 100 and 300 m3/h during one week.

Photo 5: Water pumping device in the flooded area of Diamaguène Centre - School 5

In order to speed up the pumping operations, ONAS installed a fixed and more powerfull pumping system at the most vulnerable site in September 2016 (Photo 6). This device is connected to a former lateritic quarry located on the south-eastern outskirts of the city by pipes buried about 1 m deep. This former quarry was to serve as a receptacle for the pumping water. However, the device never operated correctly due to the poor quality of the material used, the location of the receptacle uphill and the lack of electicity for the electrical pumps during stormy weather.

Photo 6: ONAS pumping device in the school yard of School 5 (Diamaguène Centre district) in the rain season

3.4 Flaws of the flood management system

3.4.1 Failure to take into account hydrometeorological information

The analysis of rainfall during the most important floods of 2010, 2013 and 2016, shows two remarkable characteristics: annual rainfall of 1195.1 mm in 2010 [21] representing the highest level of rainfall in 87 years, and daily maximum rainfall of 166.3 mm in 2013 [22] and 175.1 mm in 2016 [18], although it lasted only a few hours. Therefore, as indicated [9], the greatest damage was observed during these daily maximum precipitation events in 2013 and 2016. Although this information can be very useful for prevention purposes, this meteorological information is only used to describe the context and thus the need for crisis intervention in the reports of the DFCC actors. There is no information on the runoff that causes flooding in the city.

3.4.2 Limited knowledge of flooding

The main actors in charge of the Kaffrine floods are unaware of the flooding history, nor their beginning or evolution over time. This lack of knowledge of the phenomenon and its hazards [23] is linked to the lack of archiving of historical information on the events and their management by the stakehold-

ers. The people of the Flood Control Committee are hardly permanent staff members. Most of the resource persons are assigned to other regions of the country after three years of presence. Due to the absence of a written culture, the affected population is often not able to remember the exact dates of the floods' occurrence neither. There is thus no memory nor built up experience in managing the phenomenon [24].

They also have limited knowledge of the exact origins of the water flows, even if they have more or less an idea that runoff is an important factor. They explain it in the following terms: "the waters flooding Kaffrine are not from Kaffrine but water from elsewhere". Some actors go further by talking about the "overflowing waters coming from the Gambia River". As the relief makes it impossible that the water comes directly form the Gambia, these arguments show the extent to which authorities, DFCC members and the population are ignorant of the concept of watershed [25]. In fact, the flows originate in the upstream catchment areas where rain water gatters and accumulates running downstream to its final outlet in the Saloum river, passing through the city.

Understanding the flooding phenomenon including runoff is a key element in the development of flood forecasting and prevention. Yet the runoff crossing the city is unknown in terms of quantity, speed and power, due to a lack of measuring instruments. We documented that the railway functions at first as a dam, diverting runoff artificially to another district southeast at slightly lower altitudes. Without outlet, the water accumulates there till dangerlously high levels and stagnates for weeks. The neighborhood downstream the railway only floods if the railway ultimately breaks. However, the overall floods of 2010 did not cause any impact on the railway. What weather conditions are likely to generate precipitation (with what intensities) and runoff that could endanger the railway line? A study of rainfall intensities is needed to determine this relationship and answer this question.

3.4.3 Non-involvement of all actors and lack of harmonization of all actions

The analysis of the flood management system showed that key actors such as farmers and the road and railway agencies (respectively Ageroute and Dakar-Bamako-Ferroviaire) are not involved. However, DCFC members accuse these agencies of being the aggravating factors of the floods. In the downstream parts, farmers tend to block the channels to obtain a flat surface. This practice greatly alters the flow paths over time and distorts the hydraulic equipment of the road and railway infrastructure. Water that no longer passes through the tubes, find its way by flooding or breaking the railway track.

As the runoff phenomenon was previously unknown to DBF and ONAS specialists and departments [26], [27], and [13], their interventions did not take it into account. DBF interventions are contained to the reparation of its infrastructures in order to restart its activities, while ONAS proceeds through speed procedures (which means, in fact, no profound study of causes) with the installation of pumping stations. Moreover, these actions are undertaken without any exchanges with the local authorities or DCFC members, creating a set of conditions that some actors describe as uncoordinated actions.

3.4.4 Lack of means

The local autorities do not have a substantial budget for prevention, infrastructure or crisis interventions. For each flooding, they have no choice but to call for state emergency aid [30]. Yet the financial aid that the state allocates is very often insignificant compared to the humanitarian aid delivered by NGOs. This was the case during the floods of 2016: whereas the Senegalese state had set up an emergency aid and relief fund of 10 million FCFA, the NGO "World Vision", for its part, allocated 84 million FCFA [18]. Both contributions are appreciated (as the total economical cost had been estimated at 94 million and 10 thousand FCFA) but assessed differently by the population, which perceives a lack of consideration of the State.

3.5 Discussions

The urban flood management methods practiced in the town of Kaffrine since 2004 are annually reproduced without any technical improvement [28]. These same practices are also applied in some cities in Senegal [4], [5] and in the sub-region [29], [30].

The actors in charge of management do not integrate the rainfall and hydrological hazards that they use for descriptive purposes. Yet rainfall is the beginning of the flooding storry [31], generating runoff varying in quantity and intensity according to specific surface conditions [32]. Knowledge of hazards is limited due to the lack of archives and historical data on hydrology, as well as insufficient meteorological records [24]. There is little or almost no involvement of national meteorological and hydrological services competent in the study of hydrometeorological phenomena responsible for floods. The actors in charge of management rely on the meteorological services' generalist rainfall forecasts to disseminate prevention messages through radio broadcasts. Of course, this preventive information [24], [33] which has nevertheless become "one of the obligatory passages of risk reduction" [24] is not based on convincing arguments. Information on the vulnerability of flooded areas is non-existent. It is precisely the risk or the potential magnitude of the flood in sight that is unknown. The consequence is that the populations in the flood-risk areas of Kaffrine do not take seriously these warnings for flood risk. In 2016, for example, many homeowners who never imagined they would ever be affected by floods were greatly surprised by the extent of the floodwaters. Their homes were overwhelmed by the runoff, causing significant and preventable property damage [24].

Flood management requires good preparedness, failure to do so would result in catastrophical repercussions [34]. Since it is a meteorological hazard at the beginning and then a hydrological hazard at the end, hence the name "hydrometeorological", this stage necessarily requires the collaboration of the national meteorological services and the national hydrological services. Indeed, the purpose of flood monitoring is to interpret the hydrometric and meteorological data collected, to forecast floods in time and space, to alert and inform mayors in order to help the Security Services to manage the crisis in order to protect goods and people [34].

In the current context "there is now some evidence that the

climate is changing globally" [35]. It is very likely that the number of heavy precipitation events will increase. And in most tropical regions and at mid and high latitudes, extreme precipitation events are increasing more than average precipitation" [36]. These arguments reiterated in the 5th report of IPCC Group I in 2013 therefore predict an increase in the frequency and magnitude of floods. The vulnerability of the town of Kaffrine is obvious and alarming. It is therefore necessary to replace the current flood management system with a more efficient one that will take climate change into account.

6 Conclusion

The town of Kaffrine is facing recurrent flooding. In recent years, they have increased with the recurrence of exceptional rainfall with higher annual maxima. A departmental Committee for Flood Control (DCFC) has been created in order to identify emergency interventions. These are based on old management methods, which are frequently adopted in cities in developing countries (pumping, retention basins, etc.). However, these management methods have proved ineffective in the city of Kaffrine. The costs of their application are very high on the one hand, and on the other hand, the results are not satisfactory. Despite all this, DCFC still applies the same management system. The failure in flood management is linked to a lack of knowledge of the phenomenon by the DCFC, which generally carries out spontaneous management in each rain season. Experiences are neither capitalized nor archived to constitute a memory effect and allow progressive optimalisation.

Integrated flood risk management must focus on organizing society and the territory to eliminate or reduce risk, limit damage and increase resilience. Prevention thus brings together different interventions, "both in terms of reasoned management of land use, reduction of vulnerabilities and protection of populations" [15]. It therefore requires a thourough knowledge of the hazard and the terrain, particularly flood zones, as well as continuous adaptation and prospective studies. It necessarily applies to the scale of the catchment area [28], [37], which most of the DCFC stakeholders are unaware of. Taking into account runoff in small catchment areas in urban areas is very important for effective urban flood management. But unfortunately in many West African countries, small catchments are ignored due to the absence of large or perennial rivers [38] and observation data that are scarce [39].

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