Understanding Urban Flooding in Dakar, Senegal

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1. Urban flooding in Dakar

Growing worldwide interest in urban flood risk in developing countries, especially in Sub-Saharan Africa, can be viewed from a variety of aspects such as climate change, rapid urbanization or poverty. The following is a typical scenario: rapid urban growth becomes unmanageable for the “formal” procedure of development within existing legislation, and urban poor who need a place to live construct houses on a flood-prone areas, for example steep slopes or low-lying grounds near water stream. Such a process is promoted under a wide range of conditions, including change in the pattern of precipitation because of global climate change, outflow of rural population because of agricultural intensification and population growth, or poor land management systems.

Flooding has been identified as one of the major factors preventing Africa’s growing population of city dwellers from escaping poverty (ActionAid, 2006). All African coastal cities face growing urban flood risk, as a consequence of rapid urbanization, income gap, poor government capacity and many other reasons. Moreover, the poor in Africa are far more the victims than contributors to global climate change.

The same can be said for Dakar, this paper’s focus, where urban floods have become a major problem since the late 1980’s. Here we understand the complex mechanism of urban flooding and highlight some political influence in the process in the past.

Senegal has a land area of 196,722 km^2 and a population of about 12,970,000 (July 2012 est.) (CIA, 2012). Dakar, its capital city, is located at the westernmost tip of the African continent.

The definition of “Dakar” requires attention. As administrative districts of Senegal, there are “City of Dakar (*Ville de Dakar*)”, “Department of Dakar (*Département de Dakar*)”, which consists of only one city, City of Dakar, and “Dakar Region (*Région de Dakar*)”, which consists of four departments including Department of Dakar, Guédiawaye, Pikine and Rufisque (Fig. 1). Today’s Dakar Metropolitan Area covers departments of Dakar, Guédiawaye and Pikine and a part of Rufisque. In this paper, ‘Dakar’ without explanation means ‘Dakar Region’, and ‘peri-urban areas’ means the areas of Pikine and Guediawaye.

In the Republic of Senegal, more than 42% of the population lives in cities. The average annual rate of change of the urban population of Senegal between 2005 and 2010 is estimated at 3.22% (UN-DESA/PD, 2010). The region of Dakar covers only 0.3 % of the national territory but hosts about 21 % of the national population (2.6 million) and concentrates formal and informal economic activities (ANSD, 2011). The climate is semi-arid with two seasons: the dry season (October to June) and the rainy season (July to September) (Fig. 2). The average annual precipitation between 2000 and 2009 is 354 mm (Agence Nationale de la Météorologie Sénégal, 2011).

From 1980 to 2008, floods have affected an estimated 400,000 to 600,000 people a year and caused significant damage on infrastructure, public equipment and private property. In recent years, especially serious damage was recorded in 2005, 2008 and 2009. According to the government, about 360,000 people were directly affected in 2009. The cost of the 2009 flooding in Senegal was assessed at USD 104 million. The peri-urban areas of Dakar were the most affected, with the cost of flooding estimated at 82 million USD. (The Republic of Senegal, 2010)

The peri-urban Dakar is crowded with urban poor. Over 90% of the population in peri-urban Dakar lives in areas classified as slums or spontaneous settlements. It is said that its unplanned urbanization, lack and disfunction of drainage systems are major factors of flood risk (Wang, H. G. et al., 2009; The Republic of Senegal, 2010).

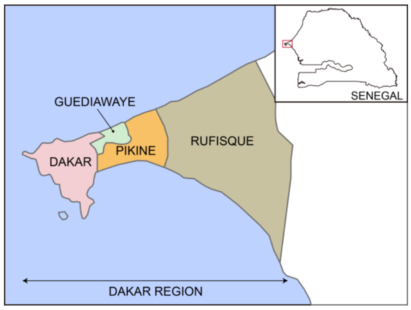

Fig. 1 Four departments of Dakar Region
Source: Author

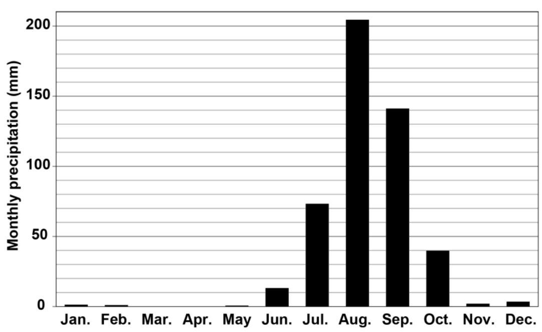

Fig. 2 Average monthly precipitation,
Dakar Hôpital (1896-1944) and Dakar Yoff (1947-2009)
Source: ONAS et al. (2010)

Generally, urban floods in Dakar are viewed as a mixture of pluvial floods and groundwater floods, combinated with artificial system failures. Jha, A. et al. (2012) define urban floods as follows:

> *Urban floods typically stem from a complex combination of causes. The urban environment is subject to the same natural forces as the natural environment and the presence of urban settlements exacerbates the problem. Urban areas can be flooded by rivers, coastal floods, pluvial and groundwater floods and artificial system failures,… (Jha, A. et al., 2012, p.57)*

Among them, groundwater flooding tends to make long-lasting direct damage. Since groundwater flooding depends on a complex mechanism of soil, it is poorly understood, often confused with surface water flooding (Hughes, A.G. et al., 2011) [1)].

In Dakar, many houses remain inundated throughout both the wet and dry seasons. There are also abandoned houses because of serious inundation over a year (Fig. 3). Urban floods have large impacts particularly in terms of social and economic losses both directly and indirectly. Besides serious health problems, residents in the flood-prone areas often suffer a loss of mobility,

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workplaces and property. Since schools are often used as a shelter after heavy rainfall, children sometimes cannot go to school for several weeks or months (The Republic of Senegal, 2010).

Fig. 3 Inundated house, Pikine, Dakar

Source: Author, Nov. 2011

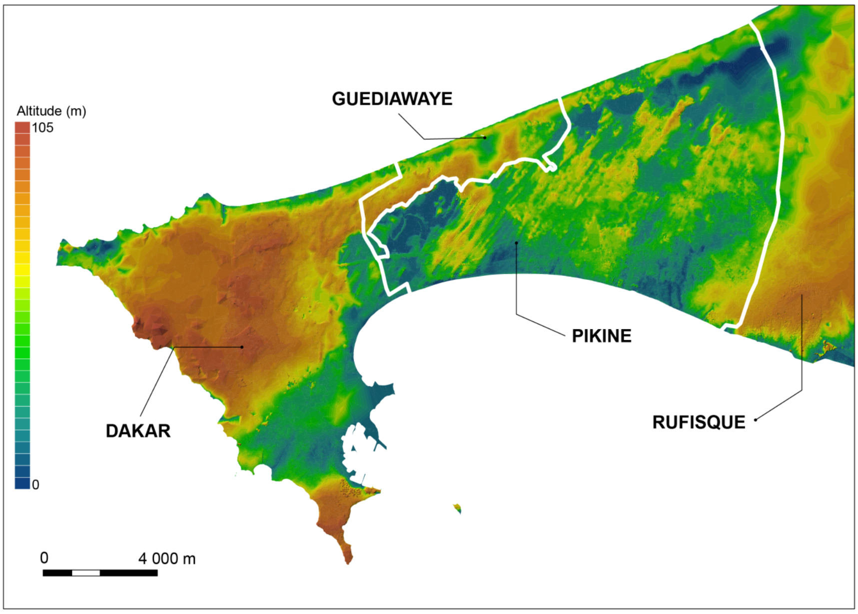

Fig. 4 Topographical map of Dakar

Source: ONAS et al. (2010), Annexe A6.2-a A3C; Legend and letters: adapted by the author.

Although many studies about flooding of Dakar have been undertaken to date, most of them understand causality of flooding only partially. Thus, the following sections will consider the direct and indirect causes of flooding based on the facts revealed by existing documents, and provide the most likely mechanism of flood occurrence.

2. Previous understanding of causality

Most literature to date understands the cause of the urban flood in Dakar as a consequence of informal urbanization and positive rainfall trend. According to Mbow, C. et al. (2008), the origin of urban flooding goes back to extreme droughts since the 1970's [2]. Using rainfall record, Digital Terrain Model (DTM) and past remote-sensing data in Yeumbeul district, one of the flood-prone peri-urban districts of Dakar, they analyzed land cover change of the district since 1954 to track the causes of flooding occurring regularly since 1989. In consequence, they describe the causality of urban flooding as follows. (1) Because of long-lasting drought since the 1970's, the rural agricultural lands in Senegal became unproductive and caused a surge of migrants to cities. (2) Meanwhile, depressions in Dakar's peri-urban areas (cf. Fig. 4) got dry up and became a possible housing site for most of the poor migrants from rural areas. (3) They acquired lands in the informal pathways and constructed informal urban settlements on the abandoned lands near water streams. (4) Expansion of built area means decreasing rainwater infiltration into soil and increasing runoff, which favors rapid flooding situations. Moreover, infrastructure networks of roads and buildings were made inside the water streams without any drainage system and became a factor in flooding. (5) Finally, the settlements in depressions make it easy for water to accumulate, causing flooding triggered by recent comeback of rainfall and extreme pluvial events. These processes can be drawn as Fig. 5.

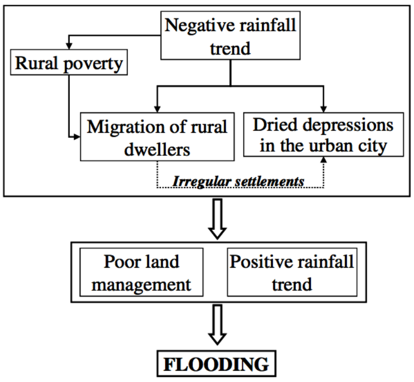

Fig. 5 Conceptual model of flooding in Yeumbeul by Mbow, C. et al. (2008)

The above-mentioned story by Mbow, C. et

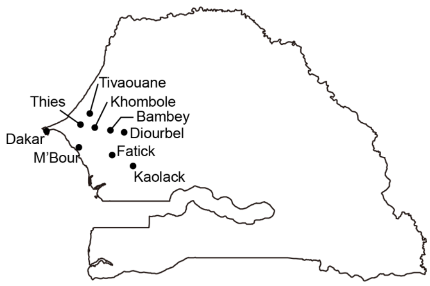

Fig. 6 Locations of the samples in Tab. 1 and Dakar

Source: Author

Tab. 1 Precipitation in 8 western regions of Senegal, 1960-1993

	Region								
Period	Bambey	Diourbel	Fatick	Kaolack	Khombole	M'Bour	Thiès	Tivaouane	Average
1960-9	645	650	690	727	622	754	595	543	657
1970-9	478	509	516	530	438	453	483	409	477
1980-9	471	411	599	549	481	465	411	436	481
1990-3	473	–	547	–	484	482	404	447	469
Average	525	518	592	602	507	551	485	458	530

Source: Guèye, C. et al. (2007)

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al. gives the outline of the interpretation by the majority of people at the time. Guèye, C. et al. (2007) collected the precipitation records in eight western regions of Senegal (Fig. 6) between 1960 and 1993 and confirmed the decrease in precipitation after 1970 in all samples (Tab. 1). According to them, *"Drought, the unequal redistribution of the rural population, the need to leave fallow land used for peanuts crops, and the impoverishment of land suitable for agriculture leave a substantial portion of arable land uncultivated. … [The rural population] migrate progressively toward Dakar, Touba and Mbour, or to foreign countries (Guèye, C. et al., 2007, pp. 89-90)"*. As is evident from Fig. 7, most of the peri-urban areas of Dakar have been urbanized between 1954 and 1985. However, we can find some questionable points here.

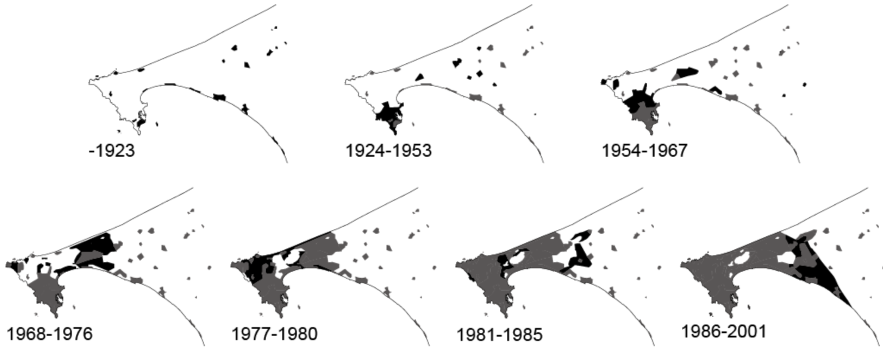

Fig. 7 Evolution of urbanized areas in Dakar

Source: Author, based on CAUS - BCEOM (2006)

First, (1) the migration of rural population to cities because of the mega-drought does not immediately lead to the occupation of lands in the peri-urban Dakar. The evolution of urban and rural population of Senegal shows rapid increases in both the total population and the rate of urban population from 1950 through 2010 (Fig. 8 and 9). Nevertheless, the curves of these parameters don't change particularly in the period of drought after 1970. Even though the drought could have promoted the migration of rural dwellers to cities to some degree, it is debatable whether the rapid urbanization in the peri-urban Dakar can be attributed only to the drought.

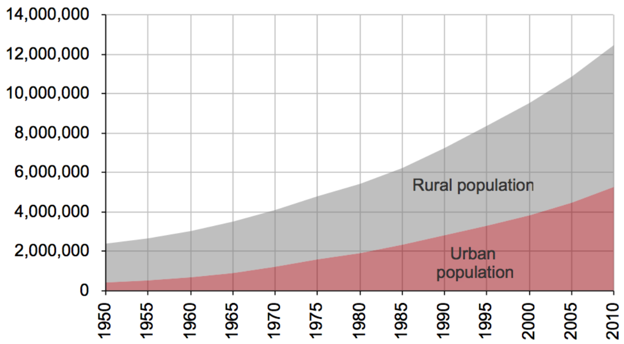

Fig. 8 Urban and rural population of Senegal

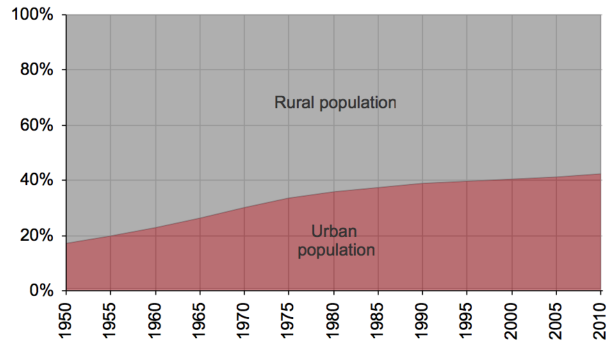

Fig. 9 Rates of urban and rural population of Senegal

Source of Fig. 8-9: UN-DESA/PD (2011; and 2012).

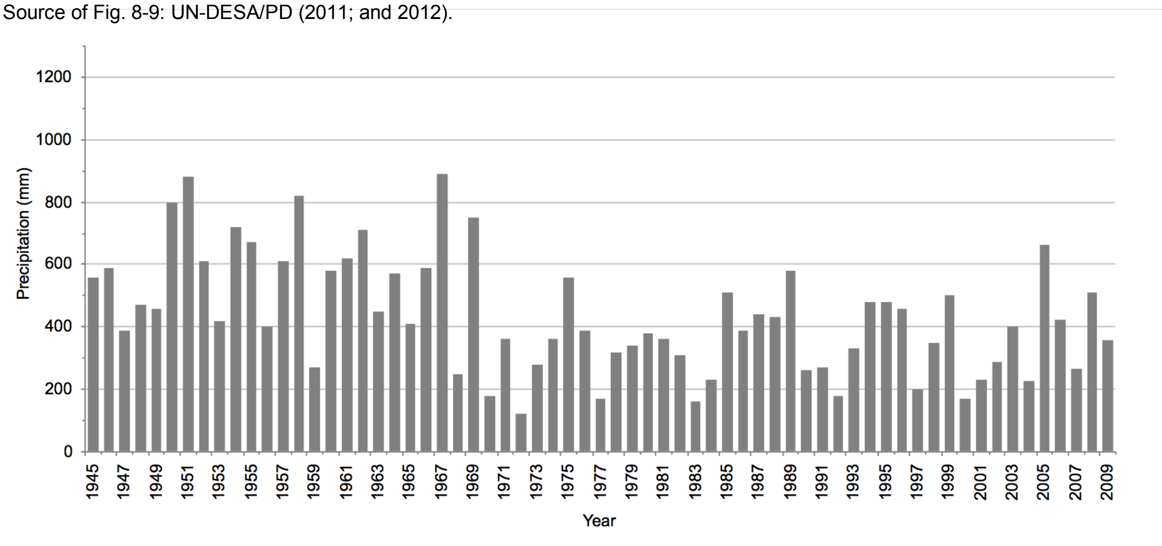

Fig. 10 Evolution of of rainfall in Dakar, 1945-2009

Source of Fig. 10-11: ONAS et al. (2010) and Agence Nationale de la Météorologie Sénégal (2011)

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Second, the cause of (2) drying up of depressions in Dakar is probably not only the extreme drought. Indeed, even in the early 1970's, there were small rainfall events in the rainy season (Fig. 10). Although the groundwater table must have dropped because of the drought, it is doubtful whether the dropped level was big enough to dry up almost all ponds in the area.

Third, (5) the recent positive rainfall trend is also questionable. As Fig. 10 shows, it is clear that rainfall in Dakar has been low since the 1970's. From 1970 to 1979, there was only one year that experienced an annual rainfall more than 400 mm, while there were four years exceeding 400 mm in each decade between 1980 and 2009. However, it would be rush to forejudge a positive trend because such a way of comparison depends largely on threshold amount. For example, the number of years in the 1970's that had annual precipitation more than 320 mm is bigger than that of the 1990's or the 2000's. When it comes to average annual precipitation of each 10 years, as pictured in Fig. 11, any obvious positive trend cannot be found in the last two or three decades. There is also no document to indicate positive rainfall trend in terms of frequency or intensity in a short time.

It is also remarkable that most existing literature, expect that in the last three or four years, has explained its cause without paying much attention to geological mechanism.

Thus, the following sections will consider the flood occurrence process in Dakar with attention to both political influence and scientific mechanism.

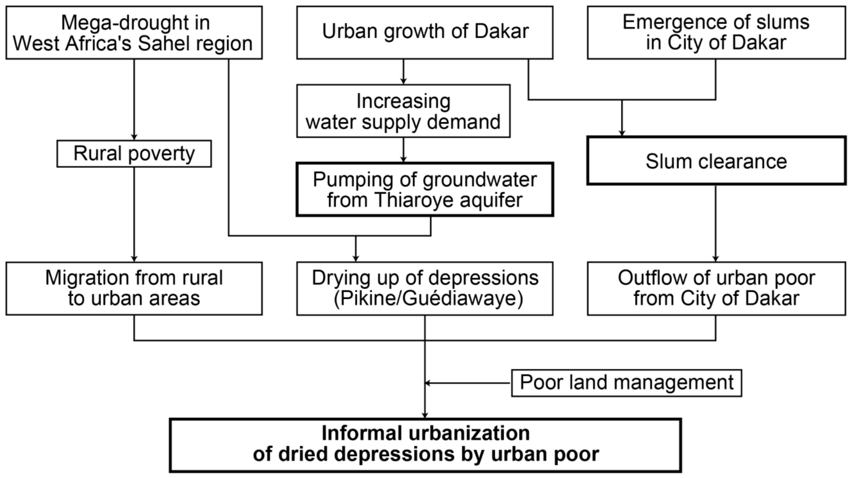

Fig. 12 Informal urbanization process in depressions in peri-urban Dakar
Source: Author

3. Informal urbanization process (1950's-1980's)

Most flood-prone depressions in the peri-urban Dakar were urbanized in an informal way from the 1950's through the 1980's (Fig. 7). If this informal urbanization is a major contributor to urban flood risk, it is needed to know why the informal urbanization happened and how political intervention affected the process.

To tell the conclusion first, Fig. 12 depicts the informal urbanization process in depressions in the peri-urban Dakar. As Fig. 5 by Mbow et al., it shows that the long-lasting drought since the 1970's caused the migration from rural areas to urban areas and drying up of depressions in the peri-urban Dakar. What should be highlighted in this figure is that there were two important governmental interventions at the time: pumping of groundwater from Thiaroye aquifer, which lowered the groundwater table, and slum clearance in the City of Dakar, which caused a massive outflow of urban poor to the peri-urban Dakar.

Pumping groundwater from Thiaroye aquifer

Dakar urbanized rapidly throughout the 20th century with an annual population growth rate of over 4.3 % (Fig. 7 and 13). As urban congestion in the City of Dakar progressed in the 1950's, the city became less able to secure an adequate supply of water. Hence, the City of Dakar started groundwater withdrawal from Thiaroye aquifer in the 1950's (ONAS et al., 2010; Faye, S. C. et al., 2004) [3]. The Thiaroye aquifer covers today's peri-urban areas, which hadn't urbanized around that time. Originally, the groundwater table of Thiaroye aquifer is very shallow (3-5 m below the ground surface). The groundwater withdrawal from the 1950's through the 1980's was intense enough to lower the groundwater table at the time (SONES et al., 2004), made the depressions in the peri-urban Dakar available to be settled (Faye, C. S. et al., 2004; USFI, 2009). The groundwater table has gradually rose back due to decrease in the withdrawal since the late 1980's [4].

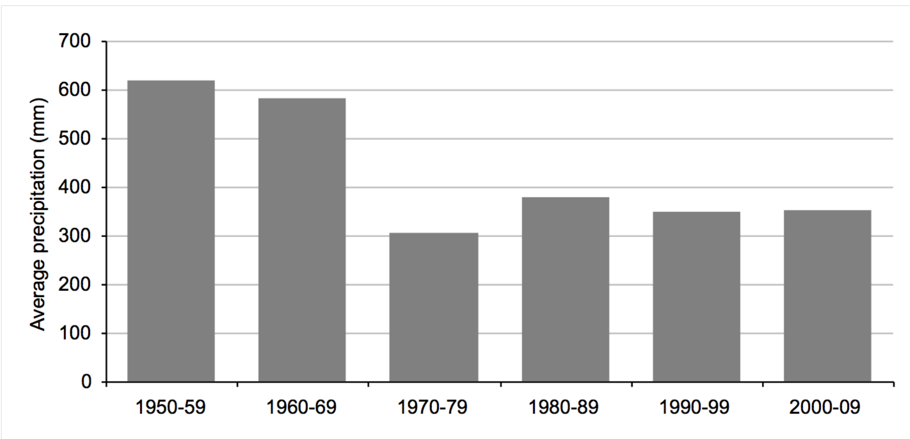

Fig. 11 Evolution of rainfall in Dakar, 1950-2009 (average of total rainfall in every 10 years)

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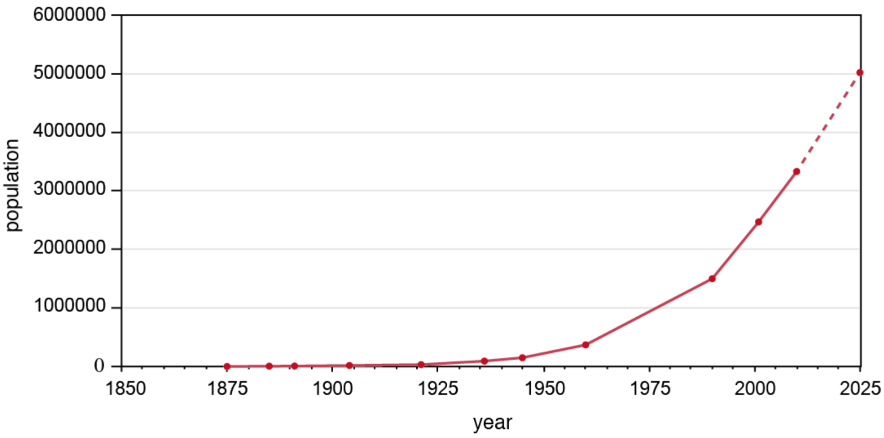

Fig. 13 Evolution of urban population of Dakar

(Dashed line: estimated population by UN-DESA/PD)

Source: Sinou, A. (1993), Diop, A. B. (2009), UN-DESA/PD (2010)

Slum clearance

Apart from the problem of increase in water demand, the urban congestion in the City of Dakar in the 1950's required dealing with unplanned settlements called as 'slums' or 'informal settlements' to respond a growing demand for land. In 1952, the colonial government founded the original form of Pikine to relocate poor urban residents of the City of Dakar. Since then, pushed out from the City of Dakar, the poor has spread out and constructed new urban areas in its periphery.

Despite the slum clearance policy conducted by the government, especially in the 1980's, and the efforts to introduce housing alternatives, informal settlements have continued to spread. In that time, the approach was the clearance of illegally occupied areas, referred to as the "bulldozer policy." This approach could not suppress the expansion of informal settlements and its impact was limited in spite of its technical and financial intervention. Because of social tensions in 1985 following a massive eviction without alternative measures such as relocation in a district of Dakar, the government decided to introduce another slum upgrading approach. Nevertheless, most today's peri-urban areas were constructed during that period of time, under pressure coming from rural migrants and the inflow of people displaced from other urban areas. (Sinou, A., 1993; The World Bank, 2004b)

As observed above, urbanization in the peri-urban Dakar is a consequence of rural migrants induced by drought and natural population increase on the one hand, and inflow of urban poor within the Region of Dakar induced by the slum clearance on the other hand. They looked for a place to live in Pikine and Guédiawaye, and progressively constructed housing in informal pathways on depressions, which were dried up because of drought and groundwater abstraction. This is the most likely process of informal urbanization of flood-prone areas in the peri-urban Dakar from the 1950's through the mid-1980's.

4. Urban flood occurrence process (late 1980's-present)

This section will examine why the above-mentioned informal urbanization causes urban floods. Here flooding in Dakar is divided into two major phenomena: excessive surface runoff (the half-left of Fig. 14) and rising groundwater table (the half-right of Fig. 14).

Excessive surface runoff

The flood occurrence process due to excessive surface runoff is relatively simple and well-known. Expansion of built environment including houses and roads causes increase in

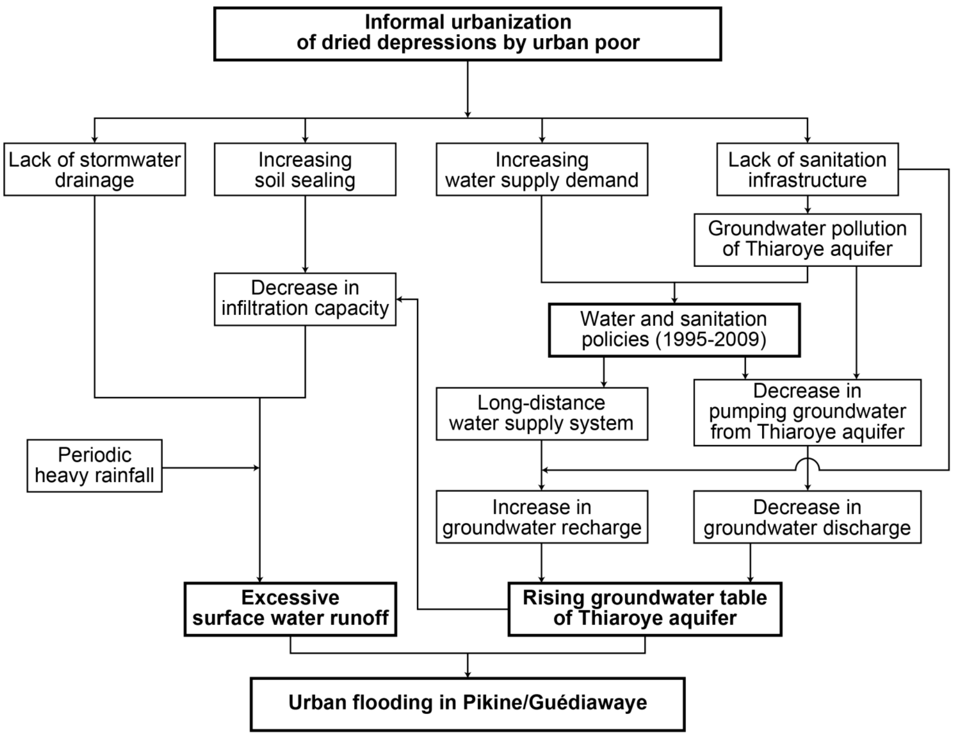

Fig. 14 Urban flood occurrence process in peri-urban Dakar

Source: Author

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(left) **Fig. 15 Septic tank of household, Pikine**; (center) **Fig. 16 Construction site of septic tank, Pikine**; (right) **Fig. 17 Cesspit, Pikine**
Source: Author, Nov. 2011

soil sealing rate and decrease in infiltration capacity. Physical and social informalities of the peri-urban areas, such as narrow and winding pathways and customary land tenure, often impede installation of stormwater drainage system. In addition, some studies mention that concrete foundations of massive facilities like roads impede groundwater flow, though this argument needs more detailed verification. Under the above-mentioned condition, triggered by periodic heavy rainfall events, or even by normal rainfall events, surface runoff can easily result urban flooding.

Rising groundwater table

As for flooding due to rising groundwater table, it is needed to trace how hydrological balance of aquifer has been changed by anthropogenic factors since the 1970's.

Along with informal urbanization in the 1970's, the peri-urban Dakar has fallen behind in wastewater drainage system. Since there is almost no collective sanitation system in the areas, most of the houses are built with septic tanks (Fig. 15 and 16), which often allow seepage from their bottoms to the water table. Firsthand observations conducted by the author in 2011 and 2012 confirmed a number of households disposing of wastewater in the immediate neighborhood (streets, cesspits - Fig. 17 and reservoirs). Despite the rising awareness and attention to groundwater pollution (SONES, 1986; Diop and Tandia, 1997; Faye, S. C. et al., 2004), the region has strongly affected by nitrogenous pollution. Re, V. et al., (2011) reported that nitrate concentrations close to 300 mg/L in a part of the areas, while the World Health Organization (WHO) recommends 50 mg/L as a limit for the drinking water supply. In addition, Faye, S. C. et al. (2004) analysed water quality data from 56 wells, aquifer characteristics, soil types and land use in the Thiaroye aquifer area, and explained the deterioration in groundwater quality by the proximity of confirmed sources of pollution to the wells.

The groundwater pollution leads to the progressively reduced pumping volume since the late 1980's. The line presented in Fig. 18 indicates the change of pumping volume in the

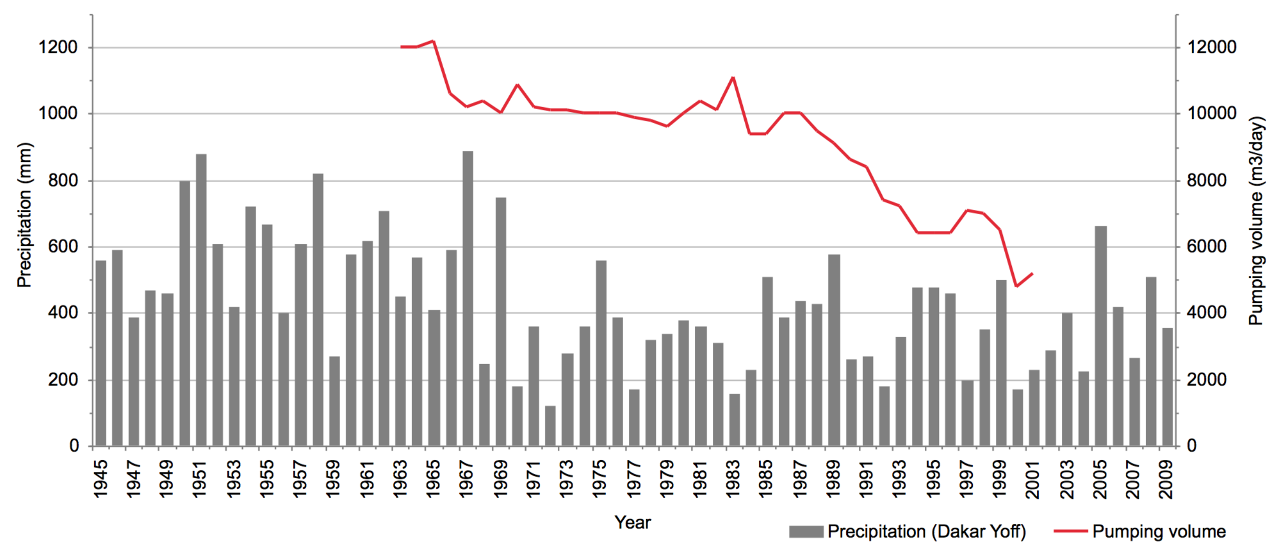

Fig. 18 Rainfall and pumping volume in peri-urban Dakar
Source: ONAS et al. (2010), Agence National de la Meteorologie du Senegal (2011)
Note: The line shows only the data that the author could acquire (between 1963 and 2001). Groundwater withdrawal from the Thiaroye aquifer was also implemented from 1950 to 1959, from 1961 to 1963 and after 2002.

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peri-urban Dakar. While it shows only the volumes that the author could acquire (between 1963 and 2001), the abstraction was already started in the 1950's, as explained in the last section, and it has been continued even after 2002 until now. The volume of pumping in the 1950's was from about 15,000 to 17,000 m^3/day (ONAS et al., 2010; Faye, S. C. et al., 2004) [5]. The groundwater withdrawal was once almost suspended between 1959 and 1961 and restarted in 1961 with a volume from 11,000 to 12,000 m^3/day (ONAS et al., 2010) [6]. As illustrated in the figure, the volume was around 10,000 m^3/day between 1966 and 1987. Because of the groundwater pollution, the withdrawal has generally reduced since the late 1980's. This period of time corresponds the period when urban flooding became a major problem in Dakar.

Meanwhile, Dakar's growing population asked for an alternative water supply strategy. Therefore, in 1995, the World Bank launched the Water Sector Project (Projet Sectoriel Eau, or PSE), followed by the Long-term Water Sector Project (Projet Sectoriel Eau à Long Terme, or PLT) in 2005 [7]. Under these projects, a long-distance water transport system was constructed to draw water from several resources in Senegal, including Lac de Guiers near the border between Senegal and Mauritania, to the City of Dakar and its suburban areas (Fig. 19).

Thanks to the long-distance water transport system, the peri-urban areas' growing population [8] could continue using water, though their sanitation system has not improved effectively. Thus, along with increase in water needs, the volume of wastewater infiltration into aquifer has continued to increase on the one hand, and withdrawal of contaminated groundwater has been decreased further on the other hand (Fig. 18). Current volume of pumping from the Thiaroye aquifer has dropped to about 2000-3000 m^3/day.

Such processes (cessation of groundwater abstraction due to an increased offer of the subsidized mains water supply and/or deterioration of the groundwater quality) have already reported in other cities, including the southern sector of Tehran, Iran, parts of Riyadh, Saudi Arabia, and London, where all experienced rising groundwater table and flooding as a result (Hughes, A.G. et al., 2011; Foster, S. D. et al., 1998).

The risk of groundwater table rebound has been repeatedly pointed out, even by the environmental impact studies of PSE and PLT (The World Bank, 1995, Annexe 8, p. 11; The World Bank, 2004a, pp. 19-20), yet, amazingly, any countermeasures have not been carried out.

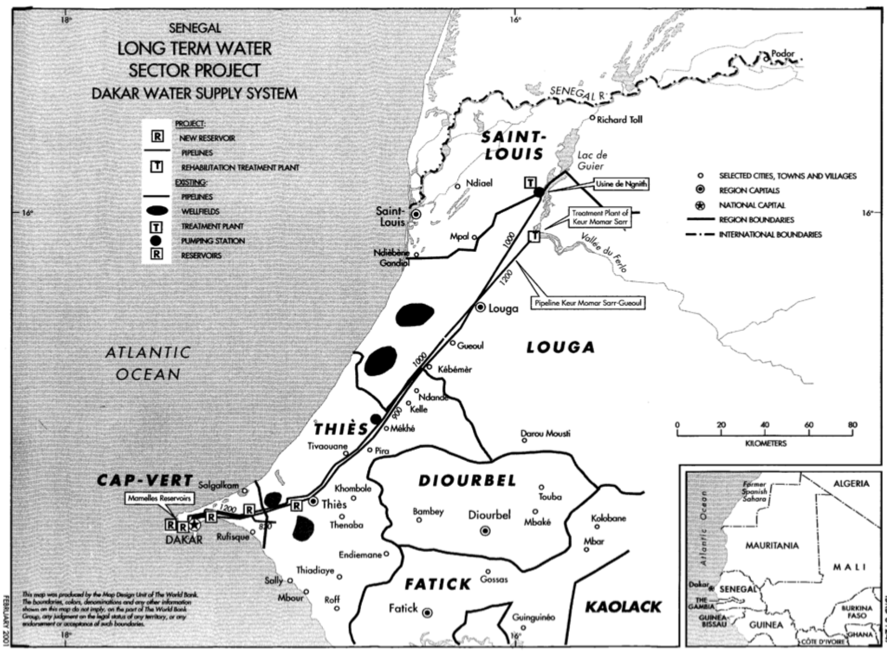

Fig. 19 Long term water sector project of the World Bank, Project map

Source: The World Bank, 2001, Annex 'Map'

SONES et al. (2004) concluded that the pumping of 16,000 m3/day would result in a 0.5 to 3 meter decrease of the level of the groundwater table [9]. It is to be noted that rising groundwater levels reduce soil infiltration capacity. Thus it also promotes excessive surface runoff in rainfall time.

Gathering the discussion above, the flood occurrence process is largely affected by the defective urban growth management. As the peri-urban Dakar grew without installation of sewer systems, wastewater infiltration has substantially increased. Following anthropogenic pollution, groundwater abstraction has been abandoned, and the water supply system was replaced by the new system depending outside water resource. This process results in a rising watertable inducing flooding.

5. Future issues

Most existing literature on flooding in Dakar tend to overrate the effect of pluvial variation, rather than that of rising groundwater. In fact, causal relationship between drought and the informal urbanization or informal urbanization and flooding has been often ambiguously explained. There is also a lack of evidence for the recent 'come back' of rainfall. This paper revealed that flooding in Dakar is a consequence of highly anthropogenic factors related to geological mechanism, rather than the global climate change or climate variability.

Past effort to improve living condition in the city has produced side effects at the same time. The slum clearance until the 1980's caused an excessively rapid urbanization in the suburbs without drainage systems. The radical reduction in water-well use, due to an increased offer of the subsidized water supply from other resources and deterioration of the groundwater quality, induced groundwater table rebound that causes groundwater flooding and promotes pluvial flooding.

From this point of view, current approaches to flooding have following fundamental problems.

Firstly, there are often overlaps and gaps between current frameworks related to the flood risk. As pointed out by their appraisal reports, for

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example, long-distance water transport projects have induced groundwater flooding as side effects, though no countermeasures have been took place. Many stakeholders are involved in flood risk management without clear roles, responsibilities or lead agency substantially responsible for overall consistency (The World Bank, 2010).

Secondly, most concept models and methodologies have confused flood events on different timescales. They are constructed on the assumption that floods are temporary events, whose affected areas will get back to "normal" once the cycle is complete. In fact, flooding in the peri-urban Dakar is roughly divided into two types: short-term flooding due to excessive surface runoff and medium-/long-term flooding due to groundwater table rising. Yet, most existing papers and reports have confused them, or they have paid too little attention to groundwater flooding, which can last semipermanently (ex.: The Republic of Senegal, 2010; Wang, H. G. et al., 2009).

Thirdly, there is often a lack of adaptation measures to the environmental change. Although groundwater flooding can be mitigated by some measures, it is unrealistic to lower the groundwater levels to the pre-urbanized situation. Coastal erosion and sea level rise, combinated with climate change, may also affect rising groudwater levels. Thus the population has to adapt from midium- and long-term perspective to the instable future environment. In practice, however, most measures against floods deal with mitigation of flood event itself, rather than adaptation to the environment change [10]. Relocation of the population of inundated areas to other areas (ADM, 2011) is one of the few adaptation efforts, though it hasn't effectively worked (Diallo, A. O., 2011). As history proves (The World Bank, 2004), intervention in relocation of individuals is always difficiult.

A potential tool to solve these problems is 'consultation framework for the management of the floods (*Cadre Régional d'Intégration et de Concertation pour la mitigation des inondations de Dakar,* ou CRIC)', to which the author is contributing as a member of a NGO, urbaMonde. In November 2011, The Regional Council of Dakar, African Urban Management Institute (IAGU) and urbaMonde have gathered principal stakeholders related to flooding in Dakar and conducted a large seminar for four days. Following the seminar, the Regional Council of Dakar, supported by urbaMonde, set up CRIC [11]. This framework will coordinate the technical services of municipalities and the actors of the civil society to harmonize their actions against the floods in the peri-urban Dakar from a long-term perspective. This policy has only just started. Although what happens from now on is the hard part, CRIC will hold a key to manage the flood risk.

NOTES

1) Hughes, A.G. et al. (2012) define groundwater flooding as follows: Groundwater flooding occurs due to water table rise. This is characterised by one or more of the following: Type 1 – Extreme high intensity and/or long duration rainfall, Type 2 – Groundwater flow in alluvial deposits by-passing river channel flood defences, Type 3 – Cessation of groundwater abstraction for Public Water Supply or mine dewatering, e.g. London Basin and other urban areas, and Type 4 – Underground structures creating barriers to groundwater flow.
2) In fact, the long-lasting drought in the West Africa's Sahel region since the late 1960's can be also caused by many anthropogenic activities including overgrazing. This paper doesn't trace back to the origin of the drought.
3) Cf. Section 4 (2) and Note 5)
4) The groundwater rebound process will be explored in Section 4 (2).
5) According to ONAS et al. (2010), the pumping was started in 1950 with an average volume of 17,000 m3/day, while Faye, S. C. (2004) explains that the pumping was started in 1952 and at 15,000 m3/day.
6) According to Faye, S. C. (2004), the groundwater with-drawal was reduced to 12,000 m3/day in 1959 in order to prevent saltwater contamination.
7) The responsible organization of these projects is the Senegalese national water company (Société Nationale des Eaux du Senegal, or SONES). PSE, PLT are taken over to Water and Sanitation Millenium Program (Programme d'Eau Potable et d'Assainissement du Millénaire, or PEPAM) since 2010.
8) According to ANSD (2005; and 2009), the population of Pikine and Guediawaye inreased from 1,027,196 in 2002 to 1,180,054 in 2008 (est.).
9) However, withdrawal of too much volume induces seawater intrusion into the aquifer. The mechanism of seawater intrusion is highly complex and related to sea level rise and coastal erosion, and it can affect groundwater table rise, too. This point also needs more detailed study.
10) It is to be noted that mitigation measures have gaps and overlaps and need improvement, as indicated above.
11) A regional bylaw (arrêté régional) of CCI was enacted in April 2012 (Arrêté 3/12/RD/PCRD/SG).

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