C40 CITIES FINANCE FACILITY

The strategic importance of building flood resilience in the Greater Dakar Region

Contents

Cover photograph: Martinez Codina

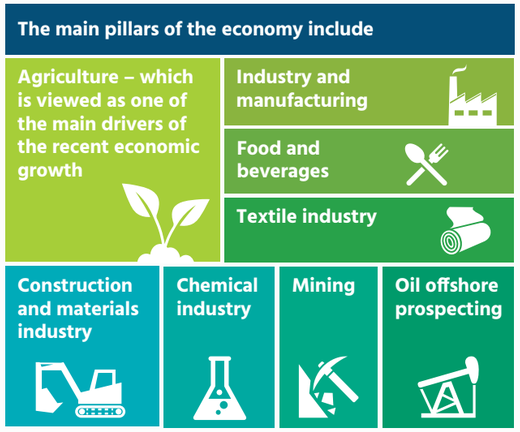
1. Introduction and context

Flooding is considered to be one of the most common and severe natural and climate-induced disasters worldwide (World Bank, 2020b).

Major as well as small flood events threaten development gains achieved to date and undermine future socio-economic growth. When flooding risks overlap with incidence of poverty, the impact of floods is more acutely felt (World Bank, 2020b). The World Bank estimates that approximately 1.47 billion people worldwide are directly exposed to intense flood risks, out of which over 600 million live in poverty (World Bank, 2020b). Africa has experienced over 750 flood events since 1970, over 50% of which was recorded in the last decade alone (World Bank, 2016). According to the World Bank (2016), floods account for the most damage costs experienced in Africa, totalling roughly 42%.

Senegal has a population of 15 million inhabitants. It is located at the western most point of the African continent and has a coastline that stretches over 530 km (World Bank, 2013), crossing six administrative districts which includes Dakar.

Over two thirds of the Senegalese population resides in urban coastal areas, which also houses over 90% of its industry (USAID, 2017). The Senegalese economy has been growing at roughly 6% over the last five years since 2015 and is one of the fastest growing economies in Sub-Saharan Africa (World Bank, 2018). This has been achieved through several waves of structural reforms to pave the way for economic development, bring about economic stability, and attract private investment.



(WorldAtlas, 2019)

Figure 1: Map of Senegal

Figure 2: Map of Dakar showing different regions

In spite of the many gains made to date and significant poverty reduction measures put in place, Senegal has a poverty rate of roughly 35% (World Bank, 2018).

Senegal has been experiencing many climate change impacts over the past few years. **Flooding has been identified as one of Senegal's main and most serious disaster risk** which is amplified by a changing and unpredictable rainfall pattern (GFDRR, n.d). **The number of people affected by floods in Senegal has increased five-fold from 170,000 in 1999 to over 900,000 in 2009, with most of them being based in the Greater Dakar region** (Schaer, Thiam & Nygaard, 2018). The existing socio-economic conditions that prevail in Senegal and Dakar can be partly explained by the numerous flood-related losses (GFDRR, 2014).

The capital, Dakar, covers less than 0.3% of the national territory and yet is home to approximately 2.4 million, or approximately 16% of the total population of Senegal. The Greater Dakar region, which is the focus of this report, includes the peri-urban areas and counts a population of roughly 3.2 million inhabitants (PopulationStat, 2019). Like many urban coastal centres in Senegal, Dakar is a low-lying city which is rapidly expanding and faces several environmental and socio-economic challenges. These low-lying areas tend to be more exposed to coastal surges and floods as well as pluvial floods. In some of the neighbourhoods of Dakar, such as Pikine and Guédiawaye, floods have become a yearly occurrence over the past 15 years (Schaer, Thiam & Nygaard, 2018).

In 2009, Senegal, and Dakar in particular, experienced devastating floods of great intensity. The agriculture sector was severely impacted and infrastructure such as roads, bridges, houses, and other buildings were damaged.

The number of people affected by floods in Senegal has increased five-fold from 170,000 in 1999 to over 900,000 in 2009, with most of them being based in the Greater Dakar region.

At present, it is estimated that approximately 40% of the population of Dakar and its peri-urban areas is highly exposed to flooding

According to a GFDRR study conducted in 2014, it is estimated that over 30,000 homes in the Dakar region were destroyed. Over and above the tragic loss of many lives, which are directly attributable to floods, the estimated damage and losses throughout the country totalled US $ 100 million, of which roughly 80% was from damage and losses in the Dakar region alone (GFDRR, 2014). At present, it is estimated that approximately 40% of the population of Dakar and its peri-urban areas is highly exposed to flooding (Diop, et al., 2017).

Rapid urbanisation coupled with a changing climate which is likely to result in floods of increasing frequency and intensity, calls for action to safeguard the lives and livelihoods of vulnerable communities and support economic growth. In this paper, we explore the effects of floods, most importantly on deepening the vulnerability of communities that are already exposed to climate hazards, and we conclude by recommending an integrated urban planning approach to addressing flood risks in the Greater Dakar region.

2. Climate change in Senegal

2.1 Historical and climate predictions

Senegal has a tropical climate and is characterised by a rainy and dry season. Temperature and rainfall variability is experienced across the country with increasing temperatures from the coast to the hinterlands. The northern region experiences a longer dry season and less rainfall than the South, with a marked difference of average rainfall of 360mm and 1500mm in the respective regions (USAID, 2017).

Senegal has been experiencing a warmer climate since the 1960s. An average increase of nearly 0.9°C has been noted, with the northern regions experiencing higher rates of warming (USAID, 2017). According to a climate change risk profile generated by USAID in 2017, Senegal has suffered many cycles of droughts for over 30 years leading to the early 2000s as less average rainfall has been experienced. Higher temperatures coupled with less rainfall and exacerbated by more unpredictable rainfall patterns have had devastating consequences on many aspects of life and the economy.

Climate change scenarios for Senegal project an average increase of 1.1°C to 3.1°C by 2060 in annual temperatures (USAID, 2017). In the future, the rainfall pattern will tend to become increasingly unpredictable, however, an overall increase in heavy rainfall events is expected, which would lead to more flooding events. In addition, sea level rise of up to one metre by 2100 will impact the liveability of low-lying urban centres and potentially cause more coastal floods (USAID, 2017).

Similar projections are expected for Dakar with a 2°C to 3°C temperature increase by 2100, increased incidence of heatwaves for up to 65-71 days of the year, and an overall decrease in the amount of rainfall but more intense periods of rainfall (Lobelia, 2019).

2.2 Climate change impacts

An extensive study conducted by the BBC world Trust Service and British Council in Senegal in 2009 revealed that the Senegalese population have lived experiences of a changing climate and they have an understanding of the inextricable link between environmental degradation and climate change and variability. Since agriculture is such an important pillar of the Senegalese economy and also employs much of the labour force, many of the lived experiences relate to agricultural activities

Senegal's history of flood-related losses has slowed down its socio-economic progress, especially since the early 2000s. By addressing the root causes of floods early on, it could have avoided much of the economic and social loss experienced. In other words, floods have been the cause of a major setback to economic growth and social upliftment in the country.

In the future, climate change will impact on climate-sensitive sectors such as agriculture – with 70% of production being rainfed - and livestock and fisheries, which account for roughly a fifth of the GDP (Climate Analytics, 2019). These climate-sensitive sectors employ a majority of the Senegalese workforce, whose livelihoods will be under threat with the intensifying of climate impacts.

Floods have been the cause of a major setback to economic growth and social upliftment in the country.

2.2.1 Timeline of floods in Dakar

Following a series of major droughts in the country, Senegal, and in particular Dakar, faced several floods from 2005. With every rainy season in Senegal, comes a flood of varying scale (OCHA, 2013).

The section below provides a timeline of the major floods in Senegal and in particular in the Greater Dakar region:

RAINFALL		IMPACT
10 heavy non-consecutive rainfall days in August	**2005**	• Widespread flooding in Dakar, in particular in Rufisque, Pikine and Guédiawaye • Thousands displaced • Millions in losses and damages
1 day of heavy rainfall	**2007**	• Floods experienced in various parts of Dakar
4 days of consecutive heavy rainfall	**2008**	• 21 suburbs of Dakar flooded with Pikine, Guédiawaye, Thiaroye and Diamaguène severely affected
Heavy rainfall received over the months of August and September	**2009**	• 360,000 people directly affected by floods • 26 reported deaths • Damage and losses to over 30,000 houses, of which most became uninhabitable and abandoned • Financial loss estimated at $82 million in Dakar due to loss and damage to public and private infrastructure
1 day of heavy rainfall	**2010**	• 30,000 households in Dakar affected
Several days of rainfall over the months of July and August	**2012**	• 26 Deaths • 264,000 people affected • 7,737 homes experienced damages • 5000 families displaced, of which half was from Dakar and Matam • Over 7,700 water drinking sources were contaminated
Heavy rainfall over the month of September	**2013**	• 163,000 people across the country directly and severely affected by floods
Heavy rainfall in August and September	**2015**	• Floods in parts of Dakar
Heavy rainfall over two consecutive days in September	**2019**	• 6 deaths in Dakar • 364 households displaced • Widespread destruction of homes, livelihoods and farming areas
Heavy rainfall over two days in September	**2020**	• 5 deaths in Dakar • Significant damage to roads and other public infrastructure – access to highway blocked

Source: Information sourced from GFDRR (2014), EO4SD (2019) and Floodlist (2020).

2.2.2 Causes of floods and exacerbating factors in and around Dakar

The scale of floods experienced in and around Dakar are the confluence of many factors. These can be summarised as follows:

Discriminatory planning under colonial rule:

Under the French colonial rule, there were several clearing of settlements from Central Dakar (Hungerford et al. 2019). These citizens were relocated to the outskirts of Dakar, whereby there was limited public infrastructure to support them and limited public services provided by the authorities. This has led to the creation of rather informal settlements such as Pikine in 1952, which today faces regular severe floods because of low absorption capacity due to a lack of natural drainage and infiltration in many parts and limited drainage infrastructure (Hungerford et al. 2019). The uncontrolled urban settlements in many parts of Dakar can be linked back to brutal policies implemented under colonial times (Hungerford et al. 2019).

Rapid urbanisation:

Droughts from the 1960s lead to a rural exodus in Senegal, which resulted in rapid urbanisation. The country faced several droughts from the 1960s-2000, which had devastating consequences on rural regions, especially on farming communities. As cycles of droughts limited economic opportunities, there were waves of settlement to urban centres in search of job opportunities and better living conditions (Schaer, Thiam & Nygaard, 2018)). As people moved to urban centres, in particular in and around Dakar, they settled in floodplains and wetland areas which at the time were dry and seemed suitable for settlement (Hungerford et al. 2019). However, as increasing rainfall was experienced throughout the country from 1990s, the hundreds of thousands of new migrants who settled in dried up areas in urban centres, found out that their homes were located in flood-prone areas. In addition, urbanisation affected the natural drainage patterns. **Rapid urbanisation, in particular when uncontrolled, can have a significant impact on natural drainage patterns (Hungerford et al. 2019). Such changes in natural drainage pattern, due to the urban fabric, can result in a larger share of the population being pushed into the flood risk category.**

Land use changes:

Rapid changes in the way the land is used have been experienced within the Greater Dakar region, with an increase in the total area covered by artificial surfaces (EO4SD, 2019). From 2005 to 2018, the main changes noted include the following:

- **50% decrease in the area used for agricultural purposes from 47.4 km2 to 21.7 km²**
- **Area covered by forests and shrublands have decreased by 50%**
- **Natural areas have reduced by 20%, from 23.5 km2 to 18.7 km²**
- **An increase of 28% in high-density residential areas**
- **23% increase in industrial and commercial activities (EO4SD, 2019).**

The above changes in land use can be largely explained by rapid urban sprawl in Dakar. The hardening of surfaces are attributed to an increase in the expanse of land covered by continuous residential, commercial, industrial, and services (such as airport and port) areas. The hardening of surfaces affects natural drainage patterns and increases surface runoff. As exemplified in the figure below, a very small proportion of the Dakar area contains green urban spaces, bare soil, agricultural area, forest and shrublands as well as land without any current use. The rapidly decreasing surface area that supports natural drainage and infiltration coupled with the lack of drainage infrastructure to effectively manage the evacuation of surface water exacerbate the impact of floods in Dakar during high rainfall events.

Limited services and infrastructure:

Due to a lack of piped sewage network, most people use latrines or septic tanks. During high rainfall events, as the water table rises, aquifers and potable water sources are contaminated by sewage as is the soil (Hungerford et al. 2019). As a result of ongoing contamination, aquifers such as the Thiaroye Aquifer, which was one of Dakar's main sources of potable water until roughly 2005, is no longer in use. According to Hungerford et al. 2019, this is because the ongoing contamination has rendered the water filtration process too expensive and it is no longer viable from a financial point of view to the city.

Infrastructure has a key role to play in building climate resilience. In a scenario where Dakar has the required stormwater infrastructure to deal with increasingly intense rainfall events and the piped sewage network to effectively treat and manage sewage, the impacts of floods would not be as severe as they are felt today. This would allow vulnerable communities to better cope with floods and the city to grow in a sustainable way.

The causes of floods and exacerbating factors enumerated above are further compounded by climate change which presents an even greater challenge. This highlights the urgency of flood adaptation measures and the need to grow the call to action louder in the Greater Dakar region.

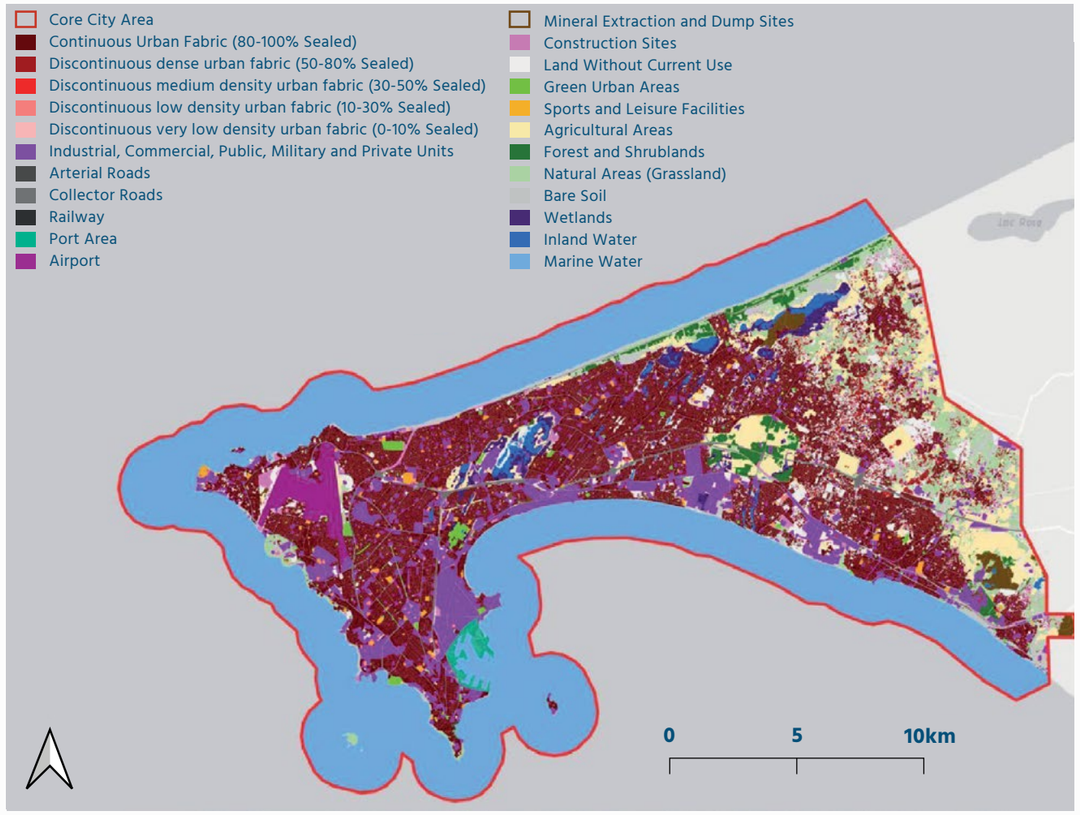


Figure 3: Classification of land uses in Dakar (Source: EO4SD, 2019)

3. Cost of floods

3.1 High economic losses associated with floods

West Africa, whilst it contributes a marginal portion of the global total emissions, faces some of the most rapid climatic changes. Floods represent a major threat to the development gains made to date and the future socio-economic potential of West African countries (World Bank, 2019). The damage to assets, loss of lives and economic production loss associated with floods – pluvial and fluvial – in 2017 in the coastal regions of Senegal, Benin, Cote d'Ivoire, and Togo is estimated at US $1.45 billion representing over 2% of their combined GDPs (World Bank, 2019). This is a significant loss on an annual basis due to pluvial and fluvial floods in coastal areas. These figures are an underrepresentation of the total cost of floods throughout these countries, which at the time of writing was not available.

It is estimated that floods – pluvial and fluvial – experienced in 2017 along the coast[1] cost the Senegalese economy a total of $230 million which is equivalent to approximately 1.4% of its GDP. The costs were calculated based on damage to assets, loss of lives, and economic production losses.

To put this in context, almost every year, there is about 1.4% of the economy that is wiped out. This leads to a larger share of people becoming further entrenched into poverty and climate vulnerability, thereby limiting their ability to bounce back from future climate shocks and stresses. To effectively address poverty reduction and climate resilience, addressing floods will have to be at the core of this work. Without a an approach centred on improved urban planning whilst addressing floods, larger swathes of the population will be made more vulnerable to the impacts of a rapidly changing climate.

3.2 Economic losses of flood events in Dakar

Devastating floods were experienced across the country in 2009, especially in the Greater Dakar region. It is estimated that approximately 380,000 people were affected by the floods with over 30,000 damaged houses in Dakar, most of which have been rendered uninhabitable and abandoned since (GFDRR, 2014). The damage and losses[2] experienced amounted to roughly US $ 82 million in losses and damage in the Greater Dakar region.

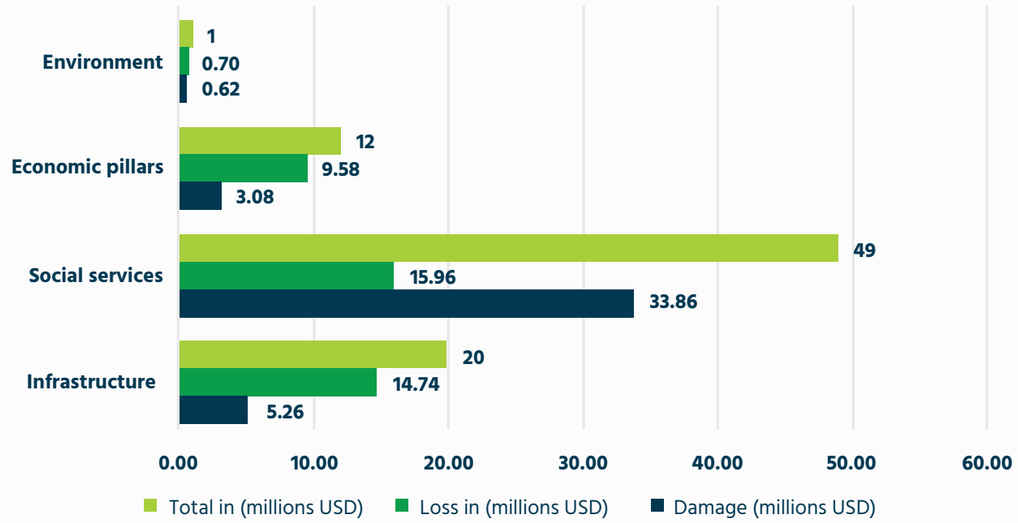


Figure 4: Damage and losses recorded in the Greater Dakar region following the 2009 floods (Adapted from GFDRR, 2014)

[1] Please note that the figures quoted relate only to losses experienced along the coast and not in the hinterlands.

[2] The difference between flood damage and loss was not made explicit in the documents consulted, it is assumed for the purpose of this report, that damage relates to the financial costs associated with repairing an infrastructure after damage has been sustained, whilst loss relates to the economic impact of the damage. For instance, according to Table 2 below, the transport sector experienced US $4.8 million in damage and US $6.5 million in losses. Using the logic explained above, the cost of repairing the damaged infrastructure is US $4.8 million and the economic loss associated with not being able to travel and transport goods is US $6.5 million.

The damage and losses faced are further explained in the table below. The category of social services which consists of housing, urban community infrastructure, health, and education suffered the largest damage and losses, making up over half of the total in 2009. Over 25% of all damage was recorded in the housing sector followed by the transport sector.

Table 2: Damage and losses in the Greater Dakar region following the 2009 floods

	Damage (in million US $)	Loss (in million US $)	Total (in millions US $)
Infrastructure	**5,26**	**14,74**	**20**
Transport	4,81	6,53	11
Water, Sanitation and Solid Waste	0,45	1,35	2
Energy	0,00	6,87	8
Social services	**33,86**	**15,96**	**49**
Housing	26,16	7,41	33
Urban community infrastructure	0,34	7,24	7
Health	4,36	1,31	6
Education	3,00	0,00	3
Economic pillars	**3,08**	**9,58**	**12**
Agriculture, breeding and fisheries	0,00	0,14	0.141
Industry/Trade, SME, Informal sector	3,08	9,43	12
Environment	**0,62**	**0,70**	**1**
Natural capital	0,62	0,70	1
TOTAL	**42,82**	**40,98**	**82**

In addition to the figures presented in the table above, an assessment conducted in the aftermath of the 2009 floods concluded that the priority recovery, reconstruction, and rehabilitation needed in Dakar is in excess of US $ 204.5 million (GFDRR, 2014).

These damages and losses are borne by the City Administration, households, local businesses, and other stakeholders. The flood-related damage and losses for the year 2009 outweighed the City of Dakar's[3] annual budget, which is roughly US $ 70 million[4] (International Observatory of Mayors, n.d) and the recovery and reconstruction needs is roughly 2.5 times the City of Dakar's annual budget.

This means that a heavy rainfall season under the current scenario of limited flood resilience interventions can potentially wipe out the City of Dakar's annual budget in recovery and reconstruction needs. Diverting funds from the annual budget to recover from floods, which in heavy rainfall years can account for a significant portion of the City's budget, has the potential to slow down socio-economic progress. Funds that could have been used to progress socio-economic development, are at times used to rebuild and recover from floods. Under projected climate change, where the rainfall regime will become more variable, it can be inferred that an increasingly larger proportion of the City's annual budget will be diverted from socio-economic growth to flood recovery. This will inevitably lead the City to the following crossroads:

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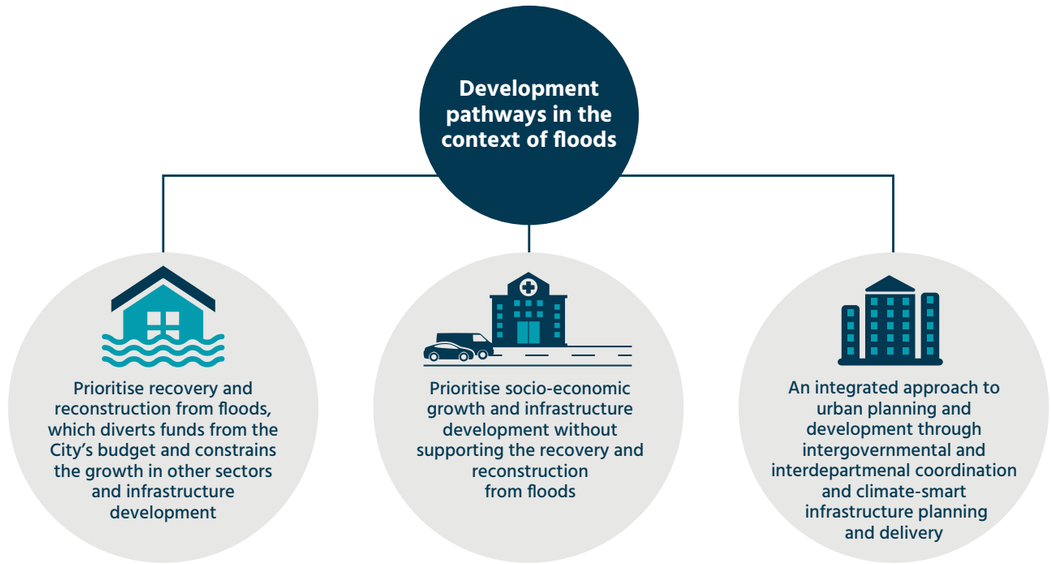


Figure 5: Development pathways in the context of floods

[3] The city's budget is different to that for the Greater Dakar region.

[4] Important to note at this juncture that the cost of 2009 floods were spread across public and private sector as well as households. The City of Dakar did not carry the entire cost of the floods. These figures are provided for a juxtaposition to provide a sense of the scale of devastation.

3.3 Cost to households

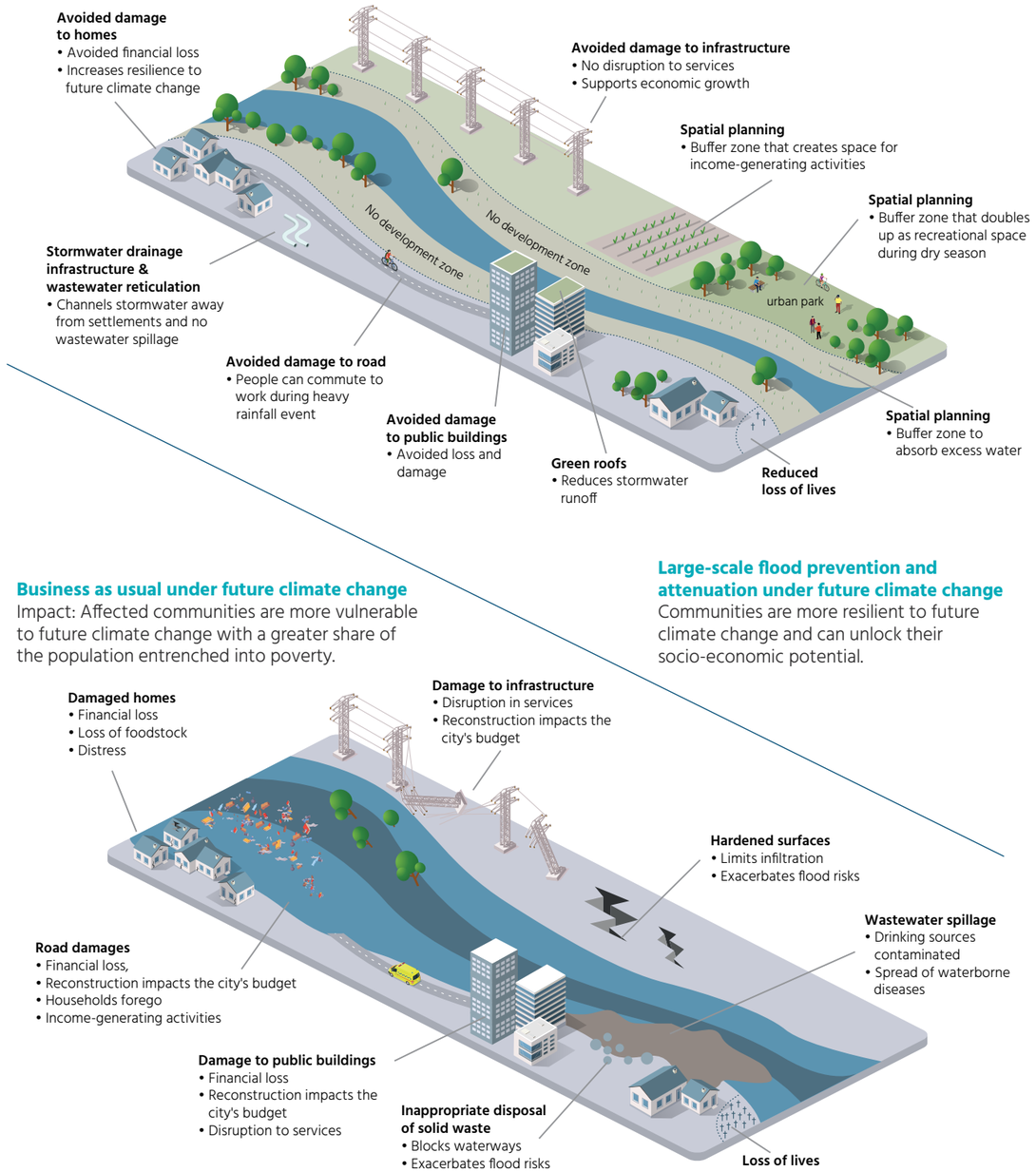
In general, floods result in negative economic impacts – with varying degree of the intensity of the impacts experienced depending on the incidence of poverty, disaster risk reduction and mitigation measures in place, early warning systems, etc. The lived experience of recurring floods in Dakar includes the following (Hungerford et al. 2019, World Bank, 2020a, and IFRC, 2020):

- Loss of life.
- Damage to homes and possessions.
- Disruption of services.
- Disruption in schooling.
- Loss of household food stock.
- Decreased productivity as affected communities spend time cleaning up their homes and neighbourhoods.
- Food insecurity.
- Living in precarious conditions with inevitable contact with contaminated water when latrines and the sewage network malfunction during floods, which often lead to diseases such as dermatoses.
- Decreased net household income as affected communities:
  - Sometimes have to forgo income-generating activities for reasons such as transport routes being disrupted.
  - Spending money on constructing rudimentary flood prevention measures.
  - Spending household income on repairs.
- Distress due to being displaced.
- Loss of the social safety net for those who have been displaced.
- Decreased quality of life.
- Disruption in inoculation schedules for children which often puts them at more risk of diseases.
- Decreased ability to pay and/or even access certain key services such as medical treatments.
- Spread of water-borne diseases, in particular malaria.

Based on an assessment conducted by the Senegalese government following the devastating floods of 2009, it was estimated that a 14% loss of household income was experienced in certain suburbs of Dakar (PDNA, 2009). However, as demonstrated by the list above, the cost of floods to affected communities in Dakar is more than financial in nature, it has far reaching economic and social impacts. Often the reporting in the aftermath of floods is focused on material losses and whilst the material losses in absolute figures may be low in poor communities, they are far more devastating in nature. As limited material possessions are washed away and/or damaged by floods and as their homes become inhabitable – for days or sometimes for longer periods of time – these households have to start from the ground up.

Whilst at times in financial terms, the loss may not appear massive, the lived experience of floods on the ground tells a different story. The impacts and recovery of floods undermine and even reverse the socio-economic gains made by households, the city, and the country.

4. Why are flood management interventions are so important in Dakar?



4.1 Locked in a cycle of flood recovery which will dilute socio-economic development efforts

If large-scale and effective flood resilience interventions are not put in place as a matter of urgency in the Greater Dakar region, floods will continue eroding larger portions of the government's budget to respond to and recover from these hazards which are only going to be getting more frequent and more intense over the years. Funds that are meant to be earmarked for education or service delivery will be spent recovering from floods. For example, in the event of devastation in the wake of a flood, the City has to divert funds – from approved projects that support socio-economic growth – towards immediate flood relief measures and start the reconstruction of damaged public infrastructure such as road, schools, hospitals etc.

As floods become more frequent, **Dakar will be locked in a cycle of recovering from floods which have the potential to reverse years of progress (World Bank, 2020b) and trap a growing share of the population into poverty.** This will significantly hamper its ability to meet its development goals. It is fiscally prudent to invest in large-scale flood prevention and management interventions in the Greater Dakar region to safeguard its future socio-economic development. By doing so, not only will the government alleviate the City's budget and prevent losses borne by households and businesses; it will also provide a pathway to unlock the socio-economic economic potential of millions and advance its own socio-economic development agenda.

4.2 Undermine the affected population's ability to absorb future climate shocks

Households tend to bear the brunt of the impact floods. Hard-earned belongings are lost, they have to pay for repairs to their home structures, at times roads cannot be accessed which means that they cannot go to work thereby forfeiting a portion of their income, businesses cannot operate for days if not months because of stagnant waters, people end up being into contact with wastewater which flood their streets and homes which unfortunately can lead to contracting water-borne diseases. Households often remain without electricity and clean drinking water for extended periods of time . This cannot become the way of life for Dakarois!

These recurrent floods, without the appropriate prevention and management interventions in place, erode the adaptive capacity of affected communities to recover from future floods and other climate-related hazards. In other words, when the next climate-hazard (e.g a drought) hits Dakar, those who have been routinely affected by floods and bore the financial and economic losses over the years, will have limited adaptive capacity to recover in the future. They will become more at risk to future climate change. Because of the slow pace of the delivery of services and in the context of a rapidly changing climate, the sad reality is that these affected households will suffer additional flood-related losses in the future.

The implication is that these affected communities can potentially be further locked into the poverty cycle, with limited ability to get out of it in the future unless large-scale systemic changes are implemented at a fast pace. As the impacts of climate change intensify, the affected communities will be further weakened and locked further into poverty, with limited options to break the cycle. In this case, it is becoming increasingly clear that floods have the potential to reverse decades of progress in the Dakar region. The call to the Dakarois government is that **the economic development of the country, of which Dakar is the economic powerhouse, will be determined by its ability to accelerate large-scale flood resilience.**

4.3 Flood response

The National and Local Governments have spent hundreds of millions of dollars in flood emergency response and prevention programmes since 2009. These funds have been secured through loans and grants from development banks, other financial institutions, and have also been financed from the government's own revenues. The interventions have been largely focused on:

- Improving the stormwater management reticulation network
- Rainwater capture and storage
- Drainage of low-lying areas
- Additional water pumping stations to drain key areas
- Creation of water retention basins
- Improved understanding of flood hotspots
- Relocation of highly exposed communities

Despite the many programmes and strategies put in place, devastating floods remain a frequent occurrence in the Greater Dakar region and in other urban centres in Senegal. These programmes have not necessarily achieved the impact intended on the ground and the affected communities continue facing the impacts of floods year after year (Schaer, Thiam & Nygaard, 2018). There are several underlying reasons documented in the literature that explains the lack of progress in effectively building flood resilience. This is beyond the scope of this report. In its Climate Action Plan5, Dakar will identify and prioritise flood management interventions to build flood resilience in the city. **Floods are multifaceted and addressing them requires a multi-pronged approach using a climate lens to plan, finance, and implement infrastructure.**

[5] The Climate Action Plan outlines Dakar's priority climate-related actions to be implemented on the ground to build resilience and/or lower its emissions. It was launched on 30 March 2021.

5. A multi-pronged approach to address floods

Recognising that the prevention and management of floods occur within complex political, regulatory, and institutional spaces, this report is by no means all-encompassing but rather takes a stance on advocating for a coherent, multi-faceted and intergovernmental transversal approach and the use of proven and cost-effective solutions.

It is acknowledged that there are major structural works that would be required in and around Dakar to build flood resilience and deliver on the backlog of services. Firstly, this report does not provide an analysis of the nature and scale of such infrastructure but rather provides a lens through which to plan and design such infrastructure. Secondly, the argument put forward relates to the transversal intergovernmental coordination that is required to deliver comprehensive flood interventions. Thirdly, numerous low-cost, high-opportunity interventions are proposed that could be put in place to limit the impact of floods. Each approach has to be adequately contextualised and further investigated for the prevailing context in the Greater Dakar region.

5.1 Future- and climate-proofing of infrastructure

To safeguard the lives and livelihoods of citizens, it is of critical importance that all public infrastructure is planned with an understanding of the impact of future climate and future demand. The principle underpinning the decision-making process for climate-proofing of investments into public infrastructure is to determine whether the planned infrastructure will perform as intended under present and future climate risks (UNDP, 2011). This avoids locking in high levels of investments, which often public infrastructure projects require, into projects that will buckle under future climate scenarios (UNDP, 2011). Similarly, the underlying approach for future-proofing an infrastructure is to determine the future demand on services so as to plan and build in a modular way so that demand for services can be met by supply or can be rapidly deployed to do so.

Social and economic development cannot be dissociated from climate change. **Focusing on development-related infrastructure now and delaying building climate resilience to a later stage can be a fatal mistake that can severely slow down economic growth and undermine development gains made.** Instead, infrastructure aimed at improving social and economic conditions should be climate-resilient to ensure its long term positive impact. To ensure that the infrastructure investments made today in Dakar do not end up in stranded assets, the city should collaborate closely with the relevant government departments and research institutions to model the impact of future local climate conditions on infrastructure. In so doing, Dakar would avoid massive investments in assets that can become stranded in the future, which can further compound the flooding issue.

An example of climate-proofing: A city is planning to build mini-hydropower stations to increase the share of renewable energy on the grid. Before investing in the construction of the hydropower stations, the city should investigate the future climate patterns – in particular precipitation, temperature and humidity in this case – to determine whether there would be enough rainfall to supply its rivers that will feed into the hydropower station over its life expectancy. This will avoid investing large sums into the development of the hydropower station that can potentially become a stranded asset if there are long periods of droughts based on local-level climate projections.

Another example for this particular context: Sustainable urban drainage systems are being planned. In the planning process, the city should seek information on future rainfall patterns and build drainage systems that can channel the volume of stormwater expected during high rainfall events. In addition, the city should obtain information about the increased in hard surfaces and the likely impact on the planned drainage system. Thereby ensuring that the infrastructure investment today has factored in future conditions and deliver services accordingly. This would lead to climate-proof urban drainage systems.

5.2 Comprehensive and holistic approach to addressing floods

In accelerating the pace of development to bridge the service delivery gap in the Greater Dakar region, the government should break away from siloed planning and implementation. The cost of siloed planning and implementation is far too high with the side effect of potentially higher poverty incidence in the Greater Dakar region. The local and regional government (for the Greater Dakar region) should create a transversal working body that is representative of all technical departments to plan, oversee, and implement all infrastructure projects.

For instance, when a road is being planned, it shouldn't be left only to the Roads Department to bring the project to fruition. A transversal working body consisting of the urban planning, housing, stormwater, sanitation, solid waste management, health, finance, economic development departments should oversee the planning and construction of the road to ensure that adequate stormwater considerations, walking and cycling pathways, tree cover to combat urban heat island effect, small roadside businesses considerations, etc are taken into account. Only then will infrastructure be at the service of development!

To avoid repeating the mistakes of the past that have hampered development to date, all infrastructure planning and implementation should be coordinated through a transversal working body. Whilst this may be a time and effort intensive approach, it has the potential to maximise the co-benefits from individual projects and serve the Dakarois best.

5.3 Low-cost high-impact solutions

There are many structural and non-structural options that can be pursued to build flood resilience in the Greater Dakar region whilst accelerating climate resilience. In this section, we argue for low-cost high-impact solutions across the above categories that can support the Greater Dakar region in building its flood resilience.

For maximum benefits, all the options presented below need to be planned and implemented using a climate change lens and using a transversal working approach (described in Sections 5.2 and 5.3). The options presented are by no means an exhaustive list but provide an overview of low-cost high-impact interventions that can benefit the Greater Dakar region:

- Zoning ordinance for limited type of land use
- Floodplain management (including zoning)
- Sponge city
- Green roof
- Coastal vegetation restoration
- Sustainable urban drainage solutions
- Routine clean-up and maintenance of waterways

5.3.1. Zoning ordinance for limited type of land use

Zoning identifies the geographical distribution of different land uses and what should be permitted and barred in specific locations (WWF, 2017). Zoning policies can target high-risk zones, limited the damage of floods to vulnerable populations.

Previous cost-benefit analysis studies showed that zoning policies could generate between US $1.03 and US $2.20 of benefits per dollar of costs generated if areas with a flooding probability of up to 1% are zoned (Hudson, 2019). Conducting any zoning policies should involve engaging practitioners, government agencies, and residents to understand better, evaluate, and employ the results while encouraging public participation (WWF, 2017).

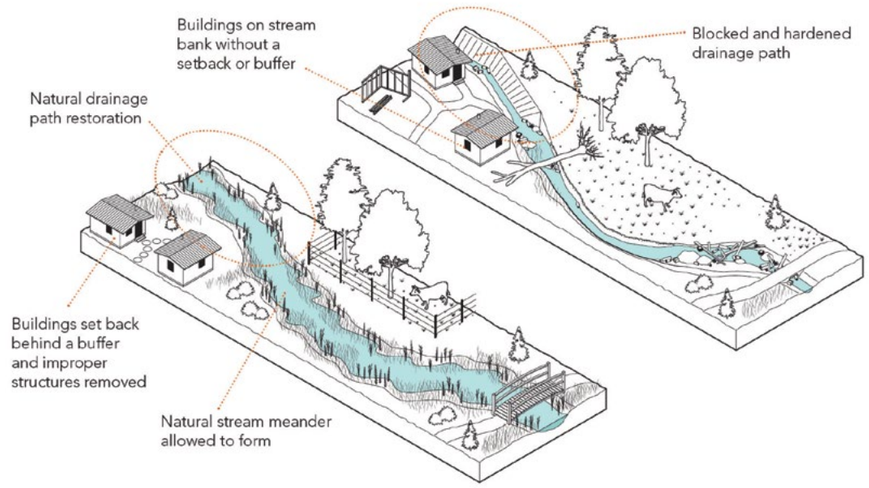


Figure 6: Improving drainage patterns to limit floods (WWF, 2016)

5.3.2. Floodplain management (including zoning)

A floodplain is a generally flat area adjacent to a watercourse where water flows in time of flood or would flow but for the presence of structures and other flood controls (WWF, 2017). If floodplains are poorly managed, it can result in flood damage to homes, roads, and any structures built in these areas and cause risk to human lives.

Floodplain management is a decision-making process with the goal of achieving wise use of lands subject to flooding (FEMA, 2007). It is important to include multiple groups with a stake in protecting their communities from flooding in the management process. Examples of floodplain management functions include zoning, building codes, enforcement, education, hazard identification programs, development/redevelopment plans, local ordinances, and control structures.

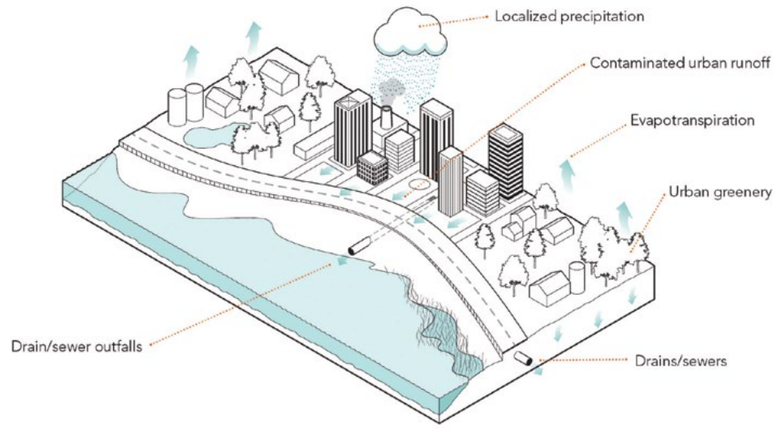


Figure 7: Improving a city's permeability (WWF, 2016)

5.3.3 Sponge city

Urban areas tend to have high amounts of paved surfaces with limited green space, which decreases the city's permeability. When precipitation falls in the city, it runs off these hard surfaces and has limited retention or interception possibilities by vegetation. This altered urban water cycle can turn average urban rainfall into localized flooding or flash floods (WWF, 2017).

A sponge city approach is a city that emphasizes the natural infiltration and purification benefits of vegetation and artificial structures that can absorb and release rainwater. Tools such as constructed wetlands, sustainable urban drainage, rain gardens, green roofs, recessed green spaces, grass ditches, and ecological parks — are examples of a sponge city approach.

5.3.4. Green roofs

Green roofs are another example of a way for cities to reduce flooding impacts through improved filtration. A green roof, or a living roof, is a roof of a building covered with vegetation planted over a waterproof membrane. These roofs can also include root barriers, drainage, or irrigation layers.

According to the University of Toronto, green roofs are an option that cities can apply to virtually any rooftop given weight load capacity. Their testing has shown that "Green roofs can capture up to 70% of rainfall over a given time, relieving underground stormwater systems and releasing the rainwater back into the atmosphere." (Hill, 2017). In addition, an example from the Seveso river basin showed that widespread green roof implementation significantly reduces peak runoff rates and runoff volumes by up to 30 and 35 %, respectively, in the case of 100 % conversion (Masseroni, 2016).

5.3.5 Coastal vegetation restoration

Coastal vegetation such as mangroves and wetlands provide essential natural protection from coastal and tidal flooding. These ecosystems can significantly dissipate wave energy and reduce inland flooding (WWF, 2017). However, human activities in coastal areas have been increasing over the past century and contributed to the further erosion of coastal zones and vegetation (Scavia et al., 2002). This coastal erosion has increased the damage from floods, including property damage, undermining tidal flood defences, and land loss with economic value (Scavia et al., 2002).

The most common approach to coastal defence has been the use of hard infrastructure solutions. These solutions involve building artificial structures such as sea walls or breakwaters to reduce or stop the impact of coastal flooding. Hard infrastructure solutions tend to have a high impact on the environment and require expensive maintenance (Ortega, 2015). Due to the high price and impact of hard infrastructure, cities are turning more to soft infrastructure approaches, including planting/caring for wetlands, mangroves, and dune vegetation. These solutions are less expensive, longer-term, less invasive, and often more attractive. Using coastal vegetation to prevent flooding works with the natural environment of the area by using the natural materials, features and processes to absorb or reduce wave impact.

5.3.6. Sustainable urban drainage solutions

Traditional drainage systems in a city are usually large structural projects with concrete pipes and underground tunnels . When the city expands, it requires a significant amount of time and cost to restore and install a revised or additional system. Such an inflexible drainage system creates cities that lack sufficient flexibility to adapt to changing circumstances and weather patterns (WWF, 2017). In addition, in many cases, these conventional drainage systems directly channel polluted water to nearby watercourses.

Sustainable urban drainage systems can help alleviate urban flooding by storing surface water at the source, decreasing flow rates to watercourses, and improving water quality. In this way, sustainable urban drainage systems can also largely alleviate non-point source pollution's adverse impacts on urban water bodies (Zhou, 2014). Such solutions rely on local treatment, retention, re-use, infiltration and conveyance of water runoff in urban areas and thus are in better agreement with sustainable principles (Zhou, 2014).

5.3.7 Routine clean-up and maintenance of waterways

eThekwini Municipality (Durban) in South Africa has piloted a programme over the past decade that focuses on the routine clean-up and maintenance of watercourses by removing (i) litter and solid waste; and (ii) alien vegetation from rivers and banks. The programme was conceptualised to lower flood risks in Durban and limit flood-related damage to public infrastructure in the city.

The programme currently covers 300km of watercourses within the city and financed by Durban's own budget. The work is performed by cooperatives who receive training and the appropriate protective gear. Each co-operative is allocated a length of 5 km of river/stream to clear and maintain. Currently, the programme is implemented by 59 cooperatives, which includes 472 workers in the city at the cost of US $1.8 million annually. In addition to lowering flood risks and limiting flood-related damages to public infrastructure, the benefits of the programme are:

- Job creation
- Local economic boost with green economy opportunities (plastic collected from watercourses are turned into productive uses)
- Improved ecosystem services
- Functional places of recreation
- Opportunity to support food gardens on river banks

Based on a cost-benefit analysis of an expanded programme – which would also include replanting with indigenous vegetation – across the whole city, every dollar of investment in the river management results in US $1.80-3.40 in municipal and societal benefits. Over the next 20 years, the upscaling of the programme to cover all of Durban's watercourses – all 7400 km – will require US $0.5 billion and will yield approximately US $100 million in avoided damage to culverts, US $0.8-1.6 billion in societal benefits, over 9,000 fulltime jobs, and significant opportunities to green economy interventions.

6. The C40 Cities Finance Facility's (CFF) work in Dakar

In the light of the urgency of addressing flood risks in Dakar, the Dakar City Administration in collaboration with the C40 Cities Finance Facility (CFF) have been working on improving the functioning of a water retention basin in Grand Yoff.

The basin was constructed in 2005 to channel stormwater and mitigate floods. It is 8 ha in size with 165,000 m3 carrying capacity. Instead of functioning as a water retention basin during the rainy season and being largely dry during the other months of the year, the poor management of the basin has resulted in approximately 70% of it being untreated wastewater. The large volume of wastewater in an open-air basin significantly impacts on the quality of life of the residents of Grand Yoff. During heavy rains, the basin often overflows which results in a significant volume of wastewater flooding the streets and houses in Grand Yoff. The flood management potential of the basin has been significantly reduced and instead of the basin has become the source of many challenges.

Figure 8: The Grand Yoff basin shown in green and the catchment area in red

Figure 9: Cross section of the basin after proposed interventions (CFF, 2020)

To transform the basin, improve its functioning, reduce flood risks in Grand Yoff (Dakar) as well as integrate it within the urban fabric, a partially submersible urban park is proposed. A section of the basin will be transformed into a park that can be used for recreational purposes during dry months and will be submerged – partially or entirely depending on intensity of precipitation – during the rainy season. The following workstreams are proposed in light of the feasibility study recently completed.

WORKSTREAM 1
Improved stormwater water management into the basin

WORKSTREAM 2
Rerouting of wastewater away from the basin into the appropriate reticulation systems

WORKSTREAM 3
Creation of a multi-tiered basin that limits floods

WORKSTREAM 4
Improved urban planning surrounding the basin

As a result of the proposed management interventions, the basin which currently floods almost every year (shown to the left of the dotted line) will be transformed into a multi-tiered basin which will fill up incrementally (shown by the maps to the right of the dotted line). Following the proposed management interventions, the basin is unlikely to flood, except in the case of exceptional rains.

This multi-faceted project, to the tune of US $ 13 million, will lead to multiple impacts and benefits for Grand Yoff, listed below. It is a relatively small investment that has the potential to significantly increase the climate resilience of the residents of Grand Yoff and prevent further locking the affected community into poverty.

- **Reduce flood risks**
- **Reduce economic losses associated with floods (borne by City administration and households)**
- **Limit interruptions to economic productivity**
- **Improve the quality of life of the residents of Grand Yoff**
- **Improve solid waste management**
- **Improved wastewater management**
- **Creation of a functional recreational space**

Figure 11: Projected impacts of the project in Grand Yoff

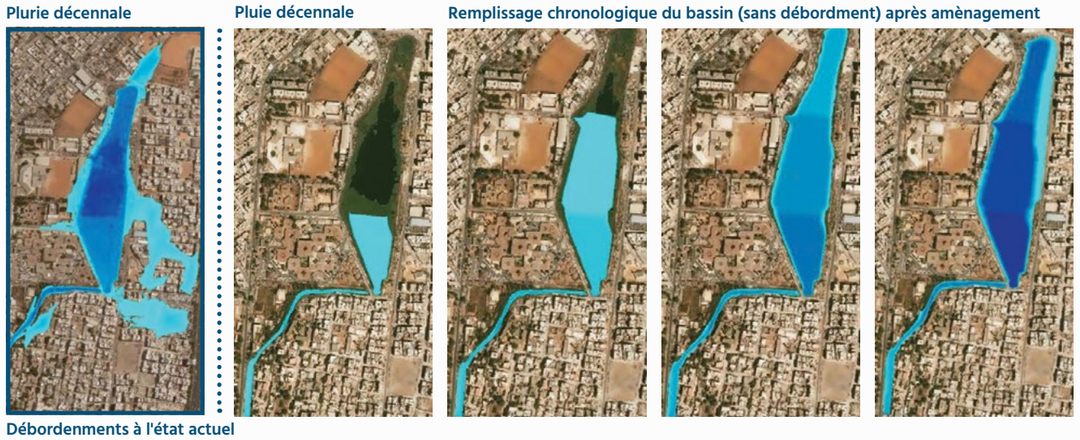
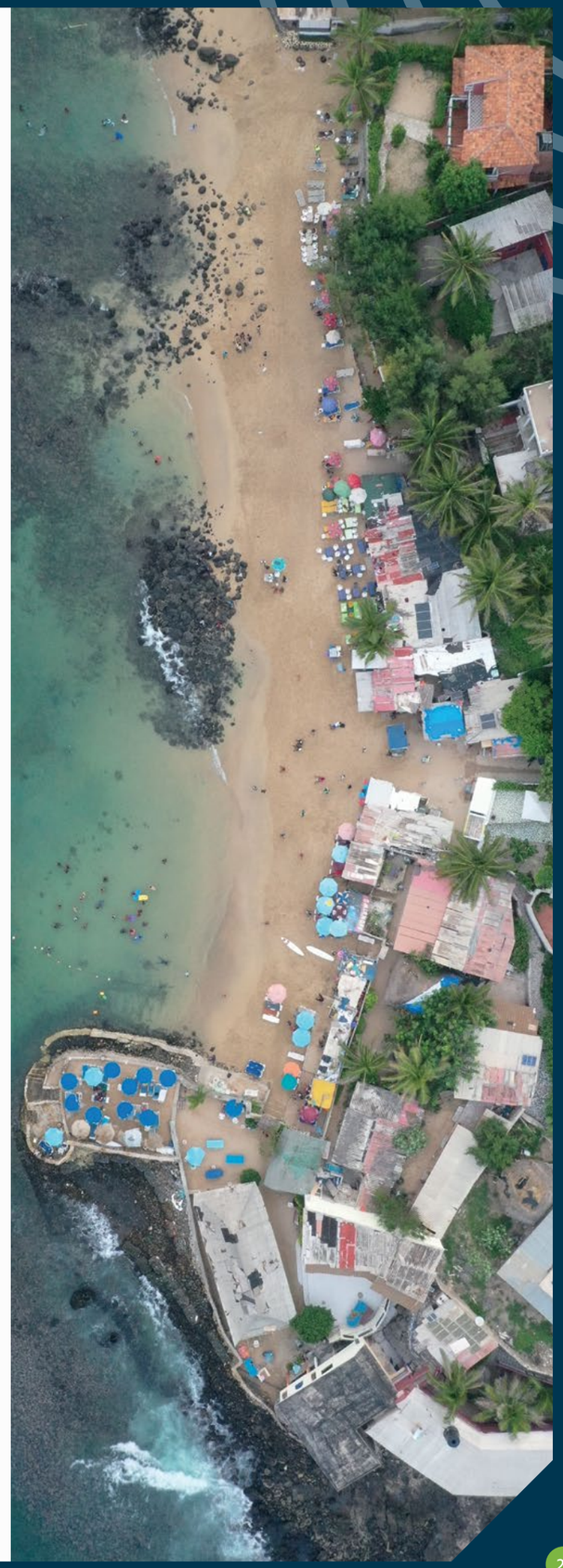


Figure 10: The map on the left shows the basin when flooded after heavy rainfall. The maps to the right of the dotted line show the basin after the implementation of the proposed management interventions.

7. Conclusion

Floods have and will continue to constrain socio-economic development in Senegal and in the Greater Dakar region and entrench a greater share of the population into poverty. In the face of a rapidly changing climate, floods of increased intensity and frequency will deepen the vulnerability of the Dakarois population to future climate-related hazards and economic shocks (such as the one brought on by the Covid-19 crisis) and limit their ability to bounce back. The widespread lived experience of floods thus far cannot become the way of life. An integrated approach to urban planning is paramount for the City to effectively deliver on poverty reduction, service delivery and infrastructure development in the Greater Dakar region.

A multi-faceted, intergovernmental and interdepartmental approach to urban planning with a strong focus on future climate change needs to be adopted to avoid the growing risk of stranded assets, higher incidence of poverty, draining of municipal coffers, and loss of lives and livelihoods. Being the economic powerhouse in the country, the future of the economy will largely depend on its ability to address floods whilst delivering on infrastructure and services. As floods will intensify in the future, the time to act is now.



8. About the CFF

The CFF is a collaboration of the C40 Cities Climate Leadership Group and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The CFF supports cities in developing and emerging economies to develop finance-ready projects to reduce emissions in support of limiting global temperature rise to 1.5°C and strengthening resilience for the impacts of a warming climate. The CFF is funded by the German Federal Ministry for Economic Development and Cooperation (BMZ), the UK Department for Business, Energy and Industrial Strategy (BEIS), the Children's Investment Fund Foundation (CIFF) and the United States Agency for International Development (USAID).

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