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Flood risk preliminary mapping in Niamey, Niger

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12 October 2024

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12 Flood Risk Preliminary Mapping in Niamey, Niger[33]

Abstract: Flood mapping is still rare in the large cities South of Sahara. The lack of information on the characteristics of floods, the orography of the sites and the receptors hampers its production. However, even with scant information, it is possible to create preliminary risk mapping. This tool can be used by local administrations in decision making on emergency plans or on climate change (CC) action plans. From 2010 onwards, the River Niger at Niamey (1.1 million inhabitants, 123 km^2 in 2014) swelled at unseasonal times. This new river flood pattern can be linked to CC. Each flooding event affected thousands of people and homes. The steady development of areas that did not appear to be flood prone in the past is the main cause of these impacts. These areas require special measures if further impact is to be avoided in the future. This chapter presents the preliminary flood risk map of Niamey 1:20,000. The map was built up using an historic approach (flooded area derived from satellite images) and considering risk (R) as the result of hazard (H) and damage (D), R = H * D. Risk was measured according to two scenarios: medium and high probability of flooding. The inverse of the return period of river and pluvial flooding (H) and the potential damage to buildings and crops according the water depth were used. Information to measure risk components was sourced by daily rainfall and daily discharge of the River Niger from 1946 to 2014, and from high-resolution satellite images (2014). The risk map id entifies hot spots for emergency and CC action planning. The fifth district alone contains 52% of the potential damage. Ninety-nine percent of the potential damage is concentrated within 225 hectars. Reinforcing existing embankments and constructing new ones to protect these areas seems more appropriate than resettle-

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33 This chapter is created with information taken from the Atlas of local resources (Braccio and Tiepolo 2014) produced by the EuropeAid 127763/C/ACT/TPS project, supplemented by geomorphological, meteorological and hydrological data collected as part of the ANADIA-Niger project (Italian Ministry for Foreign Affairs, Directorate General for Development Cooperation). The Authors would like to thank Katiellou Gaptia Lawan and Moussa Moujaimini (National Directorate for Meteorology of Niger), Abdourhamane Daouda (Hydraulics Ministry), Harouna Mato (IGNN) for the information, Abdou Adam and Ibrahim Moussa Maiga (Niamey Municipality) for the information and field work, Alessandro Sotrios d'Acquisto and Elena Ferro for the photo-interpretation of the fields and built-up areas in the flood prone areas.

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ment. The cost of the works would equal the potential damage if it remains within 2,580 euro/ml.

Keywords: Preliminary flood risk map, Hazard, Pluvial flood, River flood, Climate change, Damages, GIS, Niamey, Niger

12.1 Introduction

In recent years, the large cities of South of Sahara have been struck increasingly frequently by floods (Tiepolo 2014a), events that are believed to be attributable to climate change (CC) (UN-Habitat 2014, 2011; Douglas *et al* 2008; Satterthwaite *et al* 2007). The initiatives to support local governments in adopting climate emergency and action plans are multiplying, such as the *Cities and Climate Change Initiative* (UN-Habitat 2012). Localising the areas at highest risk (hot spots) and estimating the potential damage are the first steps for planning the adaptation to CC. This information should be provided by flood risk maps. However, urban flood mapping in the South of Sahara is still sporadic and is mostly limited to identifying flood prone areas (Ould Sidi Cheikh *et al* 2007), main classes of receptors as built-up, farm land, etc. (Mbaye *et al* 2004; Bello *et al* 2014), occasionally estimating the amount of affected people (Mutanga *et al.* 2013; Oriola *et al* 2012; Mendelshon *et al* 2010). Few large cities have a fully-fledged flood risk map (Ponte 2014; Credel 2010; Diallo 2009) and this tool rarely estimates the potential damage. Flood mapping of a single hazard is more frequent. The main reasons for these gaps without a doubt include a deficit of information: fragmented databases or databases that are too brief to characterise CC (Tiepolo 2014a), lack of recordings of flood depth, submersion time, damage to the receptors. Another reason is the propensity to use hydrological or hydraulic models in flood mapping: an approach that requires lengthy timescales and rarely generates products that are appropriated by the local South of Sahara administration.

This chapter demonstrates that it is possible to create a preliminary flood risk map even with scant information and simplified methods functional to decision-making. The chosen case was Niamey (1.1 million inhabitants, 123 km^2). From 1998 to date, Niamey has been flooded 4 times by the Niger River. Thousands of homes have been destroyed and a large part of urban and peri-urban agricultural production has been lost. According Sighoumou *et al* (2013), the main cause of flooding would be the increased run-off resulting in the soil denudation process and consequent soil crusting after agricultural area increases and abandonment of the practice of fallow. This interpretation, however, is not based on a sound analysis of rainfall. In this regard, Panthou *et al* (2014) have found a sharp increase in extreme rainfall (by number and contribution to yearly precipitations) between 2001 and 2010 compared to previous decades. The phenomenon reached a peak in the northeast of Burkina Faso, at the

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head of the watersheds of the right bank of River Niger tributaries: Gorouol, Dargol and Sirba.

Following these disasters, various attempts at flood mapping were made. Bechler-Carmaux *et al* (2000) opened the way with a river flood vulnerability map which estimated the population and the major equipment exposed to flooding. At least three river flood event maps followed, which identified the flooded area (SERTIT 2012a, 2012b; OCHA 2012) and the flood depth (ABN/CRA 2007). However, none of these tools is functional to decision-making.

This chapter proposes instead a preliminary flood risk map that stands out from previous maps due to its purpose, approach and content. The purpose is to produce a tool for decision-making on flood adaptation measures. The data, managed in a GIS and displayed on the map, should help to identify the adaptation measures. It is a case of estimating the potential damage in monetary terms relative to affordability of adaptation measures.

In the following pages, we will introduce (i) the methodology, (ii) the hazard, (iii) the flood prone areas, (iv) the damage, (v) the risk, (vi) the use of a preliminary risk map and (vii) the conclusions.

12.2 Methodology

The determination of the boundaries of the flood prone areas was done using the historic approach (WMO 2013: 18), based upon the perimeter of the flooded areas on the occasion of previous floods. As a result, the preliminary flood risk map allows for the pluvial and fluvial flood risks to be calculated and compared. Having identified the flood prone area according to different scenarios of probability of the event, the risk (R) is determined by two components:

- Hazard (H), "a dangerous phenomenon that may cause loss of life, injury, property damage, loss of livelihoods, social and economic disruption or environmental damage" (United Nations 2009)
- Damage (D), "direct damage to buildings or motor vehicles and their contents, which requires the repair, reconstruction or replacement of the property, losses of use for industrial and commercial activities, indirect losses such as rental, resettlement costs, supplementary costs, etc." (MEDD, ONRN 2012)
  according to the equation R = H * D (UNISDR 2011; UNDP, BCPR 2010; Marzocchi *et al* 2009).

The river flood prone area was determined according to a scenario of high and medium probability of occurrence. The high probability scenario corresponded to the flood event map produced by SERTIT (2012a and 2012b) by the interpretation of data from the satellite image radar TerraSAR-X 29 August 2012, taken when the discharge was 2,105 m^3/s and the height of the water was 580 cm above zero of the flood gauge

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(corresponding to 175 m altitude). This is a plausible flooding scenario with an estimated 34% annual chance of occurrence. The flooded surface was 1,847 Ha. The key assumption was that the embarkments remained intact. The scenario of medium probability corresponded to the peak of 617 cm (discharge of 2,477 m^3/s) reached on 22 August 2012. This was the flood peak of the last 69 years. The flooded area was 3,019 Ha. The key assumption was that the embarkment on the River's left banks broken, as happened during the 2012 flood. This should have generated an increase of 759 Ha in the flood prone area. For the purposes of determining the boundaries of the flood prone area, we considered that the water line was slightly sloping: 16 cm/km upstream and 7 cm/km downstream of the Kennedy Bridge (ABN, CRA 2007: 2). Since the built-up area in the floodplain today extends along the axis of the river for 6 km to the North and to the South of the Kennedy Bridge, we calculated a variance of 138 cm between the two extremes of the flood prone area and an average value of the water level of + 69 cm to be added to 617 cm, i.e. + 106 cm compared to 580 cm altitude. Close to the Kennedy Bridge, this operation generates a water level that exceeds 617 cm but which should be considered as the precautionary principle with respect to the error between the Digital elevation model (DEM) and the real profile of the land. This operation required the production of a DEM based upon the contour lines of the IGN maps 1:20,000 and 1:50,000 (IGN 1978 and 1980) with 2.5 m interval. The two perimeters allowed for the identification of 2 areas of flood depth: 0-1 m and higher than 1 m.

The pluvial flood prone area is determinate according a high probable scenario. Using a methodology already tested in Maputo (Braccio 2014), which calculates the MNDVI index of the Landsat images, water bodies and wet soil after the rainfall on 13 June 2002 (68.5 mm), were identified on a Landsat image taken on 17 June 2002. This event is a pluvial flood with a high probability of return. Within the flood prone area, the main receptors (buildings and crops) that may be damaged were identified.

The hazard was expressed as the probability of a pluvial or river flood occurring once in the next year. The probability is the inverse of the return period: $RP = (n+1)/m$ where n is the number of years on record and m is the number of recorded occurrences of the flood/rain being considered. The discharge/rainfall annual peak was provided by the Hydraulic Ministry and by the National Meteorological Directorate, respectively. The period observed was 1946–2014, as the set of data on discharge of the river in the previous 18 years is incomplete (Abrate 2007).

Flood damage depends upon the flood depth and duration, the flood velocity and the size of the sediments in the water. In Niamey, as in other tropical cities, the damage assessment can only take account of the flood depth, since there is a dearth of information on the other components. Also, when considering only flood depth, we do not know the damage (% on the monetary value of the building) with respect to the water depth. In this case, we used the average between 2 curves stage-damage produced for buildings with one floor and no basement and for buildings with several floors and no basement similar to those that were found in Niamey (NFIP 2013; Davis and Skaggs 1992). The average values were 27% and 45% for water 1m and 2m deep

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for buildings, respectively, with one floor and no basement. Those values dropped to 23% and 34% for buildings with a number of floors. In the case of adobe housing, curves stage-damage were not used because the building collapses as soon as the water enters it.

The damage was expressed as a percentage of the cost of construction. The value of the buildings could not be acquired from the Cadastre, as it is possible to do in other countries, as informal constructions, common in the flood prone area, are not registered. As a result, the buildings were identified by way of photo-interpretation of the satellite image taken on 16 October 2014 available on Google Earth, i.e. just over two years after the great flood. Instead of the value, the cost of construction of a one-floor 4 x 6 m module in perforated concrete blocks and one in adobe plus bathroom and kitchen were estimated. In the flood prone areas, homes can consist of one, two or four modules. The costs of construction were deducted from the price list created by Zaneidou (2013) for the International Fund for Agricultural Development (IFAD/FIDA) which, in turn, is also based upon the national reference price established by the government on January 15, 2012.

For crops, the damage (D) was calculated based upon average yields per hectare and prices per kg (2008–2012) of millet and paddy in Niamey (RN, MF, INS 2013a) assuming that those crops behave like wheat, which, as is known (Förster *et al* 2008: 314), does not withstand submersion for longer than one day.

Contrary to the definition of damage provided above, we did not estimate the potential damage to building contents, urban infrastructure, vehicles, clean-up costs, losses of sales, production, or intangible damages.

In order to facilitate interpretation of the flood risk map, only the 5th *arrondissement* (fifth district) will be shown. That decision is justified by the fact that on August 22, 2012, 52% of the collapsed houses and 57% of those damaged in the whole city were located in this jurisdiction, followed at a distance by the fourth district with 36% and 37% respectively (RN, VN 2012: 4).

The receptors and construction costs are constantly evolving. In just two years in the flooded area, 20% of the collapsed homes have been rebuilt. The prices of construction materials increase significantly from one year to the next due to the strong demand for cement and iron rods to implement the national program of public works: infrastructure in Niamey (including the second bridge on the River Niger and the railway Niamey-Cotonou), the refinery in the region of Zinder, the pipeline, the construction of three cement factories in the region Tahoua, etc. Since Niger is not a producer of modern construction materials and has a limited truck fleet, the high demand of cement and iron rods increases costs. Storage costs in Niamey contribute increasing costs of construction materials. For these reasons the risk map should be regularly updated.

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12.3 Hazard

Niamey is exposed to pluvial and river floods. The inverse of the return period (probability of the flood occurring once in the next year) of the annual maximum discharge (Figure 12.1) will be used to express the hazard in the equation of the risk.

This chapter considers a scenario for pluvial floods (high probability) and two scenarios for river floods (high and medium probability). The thresholds of the scenarios are less than 3% of probability to occur in the year for the medium scenario, and more than 3% to occur for the high probability scenario. There are no scenarios with low probability (less than 1%) as the records are limited to 69 years. These ranges are used in various countries (EXCIMAP 2007).

13 June 2002 is an example of a pluvial flood (68.5 mm) with a high probability (34%) of occurring every year.

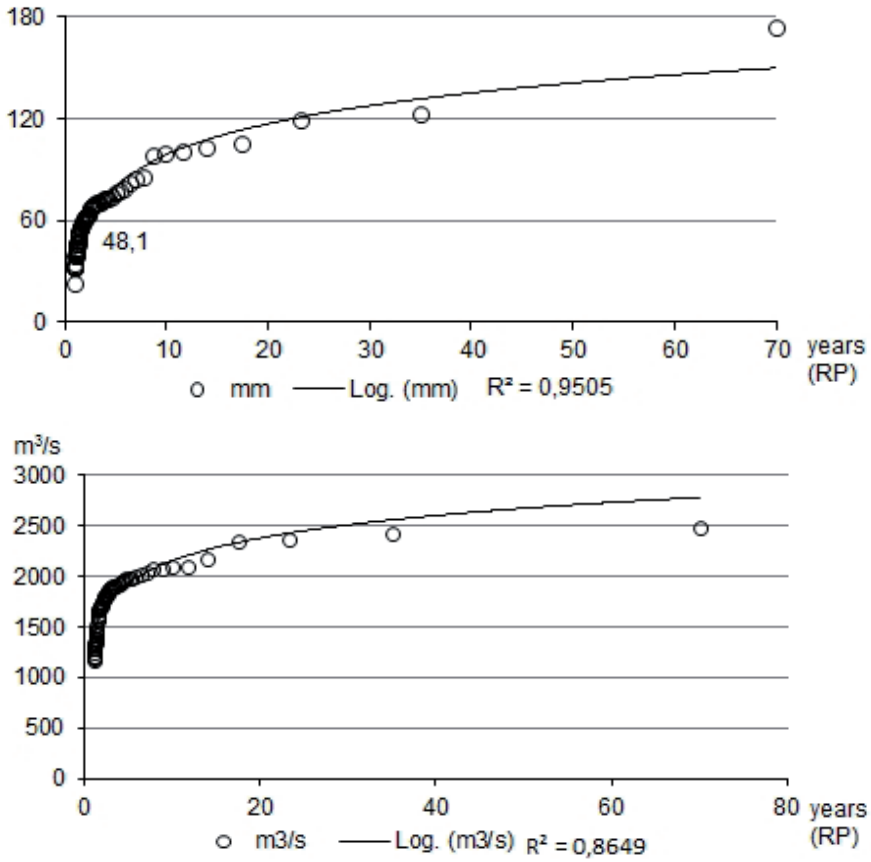

Figure 12.1: Niamey, 1946–2014. Annual maximum rainy days at the Airport (top) and annual maxium discharge (m^3/s) of the River Niger (bottom) organised according mm and return period (years)

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For river floods, the reference was the annual maximum discharge (m^3/s) of the Niger River as recorded in Niamey from 1945 to 2014. The flood stage of 22 August 2012 (2,477 m^3/s, 617 cm at the river gauge) was one scenario of medium probability (1.4%) and the one flooded on 29 August of the same year (2,105 m^3/s) was a scenario with high probability (10%) of occurring every year.

More probable scenarios do not threaten buildings or crops and therefore do not generate potential damages.

The values of expected frequency for pluvial floods and for river floods to be considered in the hazard were respectively 0.34 in the scenario of pluvial flood, 0.01 and 0.1 in the two scenarios of medium and high probability of river flood.

Regarding the exposure to disastrous natural events, Niamey has, therefore, a greater probability of pluvial than fluvial flood. In the former case, the duration rarely exceeds one day, while in the latter case it can last up to two weeks.

In the first decade of the 21st century, the heavy floods resumed but with a completely different pattern compared to the past. The river is characterized by two floods in Niamey. First of all, a local flood, which occurs between August and September, and is fuelled by rainfall on the drainage basins of the right bank tributaries upstream of the capital, known as "red flood" due to the suspended matter transported by the run-off on laterite soils. Secondly, a "black flood" originating from the upper River Niger, which comes between December and January (dry season). In the last 9 years, the local red flood exceeded the discharge of the black flood. The change was striking in 2006, 2010, 2012 and 2013 with floods in rainy season far in excess of those in dry season (Figure 12.2).

The disastrous floods of recent years have been attributed (Sighomnou *et al* 2013) to the run-off on increasingly extended denuded surfaces. Any attempt at understanding the dynamics of the phenomenon should begin with the pluviometric characterisation in the watersheds of Sirba, of Gorouol, of Dargol (in order of average annual

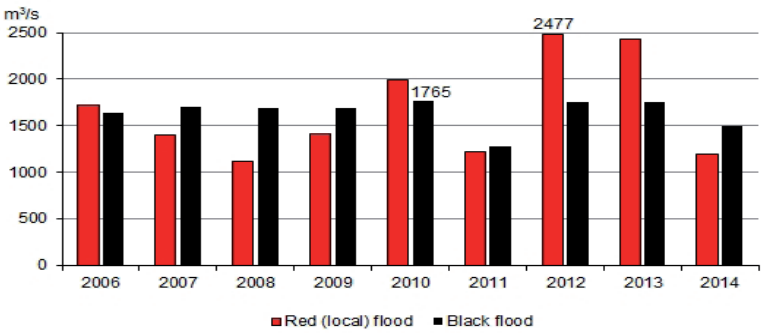

Figure 12.2: Niamey, 2006–2014. Black flood peak (black) and local flood peak (red) (source: Min. Hydraulique Niger)

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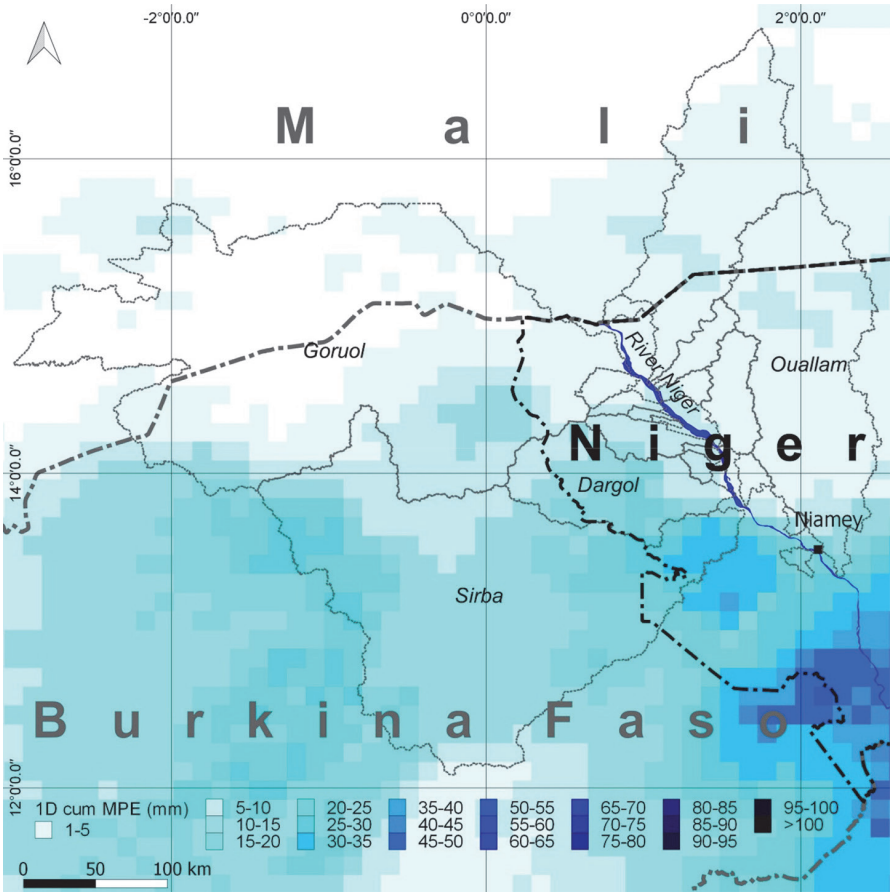

Figure 12.3: Niamey, 21 August 2012. Daily precipitation in the main catchments upstream of the capital city on the eve of the great flood of 22 August 2014 (EMMA 2012, by S. Braccio)

discharge) and the numerous intermittent creeks, i.e. on approximately 90,540 km^2, which the 5 rain gauges considered by Sighomnou *et al* do not represent adequately. In order to increase the significance of the analysis, the total daily precipitation from EMMA (2012) can be used. This analysis shows that the Niamey flood of 2012 was preceded by intense rainfall in the watersheds of the right bank upstream of the capital on the eve of the event (Figure 12.3).

August's flood peak coincides with the maturation of rain-fed crops and with the transplant of the seedlings in the paddy fields (Sido 2011). The flood, at this critical time, destroys the crops.

At this point, the event of coincidental flooding (from river and rain source on the same days) should be evaluated. If we consider the past three major river floods, it is noted that in 2012 and 2013 the flood peak was reached in the rainy season, lasted only one day, and was reached quickly. In the 4 days preceding the flood peak,

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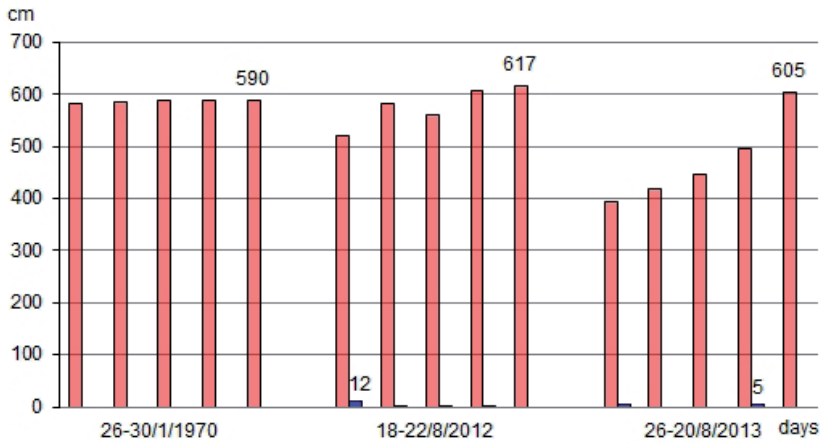

Figure 12.4: Niamey, 1970, 2012, 2013. Coincidental flooding analysis: cm of river peak (red) and mm f precipitation (blue) in the 4 days before the three main river floods of the last 69 years.

there had been a significant rainfall in Niamey only in 2012. But this event happens 4 days before the peak: too a long period to be considered responsible for the flood. In 1970 the flood peak was reached very slowly in the dry season and lasted 6 days (Figure 12.4). Up until now, coincidental flooding has not occurred, but in the future, if the river regime remains the same as the last years, it could happen. Therefore, it is worth considering both hazards.

12.4 Flood Prone Areas

The flood-prone areas were determined in the five districts according to hazard (pluvial or river flood), flood depth (0–1, > 1 m) and probability scenario (high, medium) (Figures 12.5 and 12.6). These areas are located in 4 different positions: in the flood plain of the Niger River (river flood), at the confluence of the intermittent creeks with the river, along the intermittent creeks and in the depressions, particularly on the left bank (pluvial flood). These are therefore fragmented areas, especially on the left bank.

The river and pluvial flood prone areas together extend for 28.4 km^2 (Table 12.1). However, in this enormous space, only 2 km^2 are now urbanised: 1.6% of the capital's built-up area (Tiepolo and Braccio 2015). This is therefore a very limited surface area compared to the other large cities South of Sahara provided by flood mapping, like Cotonou.

Moreover, in the fifth district of Niamey, the urbanised river flood prone area is distributed over just 4 main sites. This was a particularly favourable condition for implementing the adaptation measures as it allowed for efforts to be concentrated

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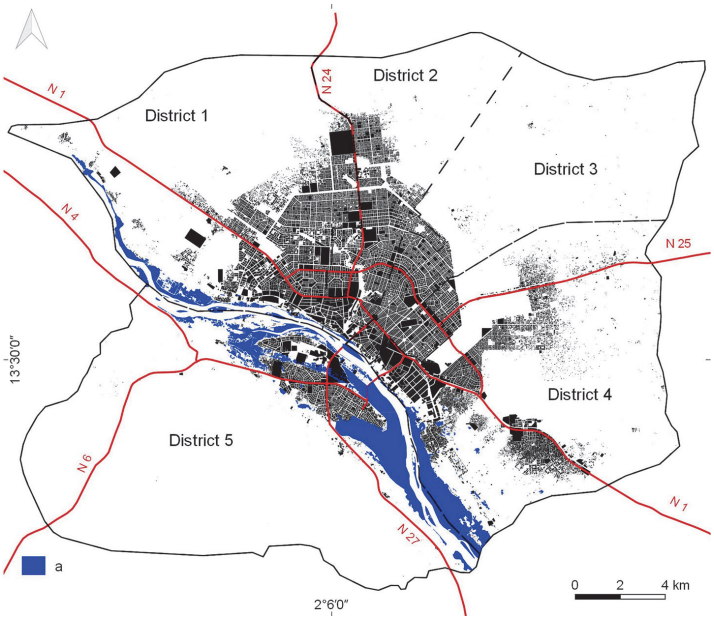

Figure 12.5: Niamey, 2014. Areas prone to (a) highly probable pluvial flood (by S. Braccio)

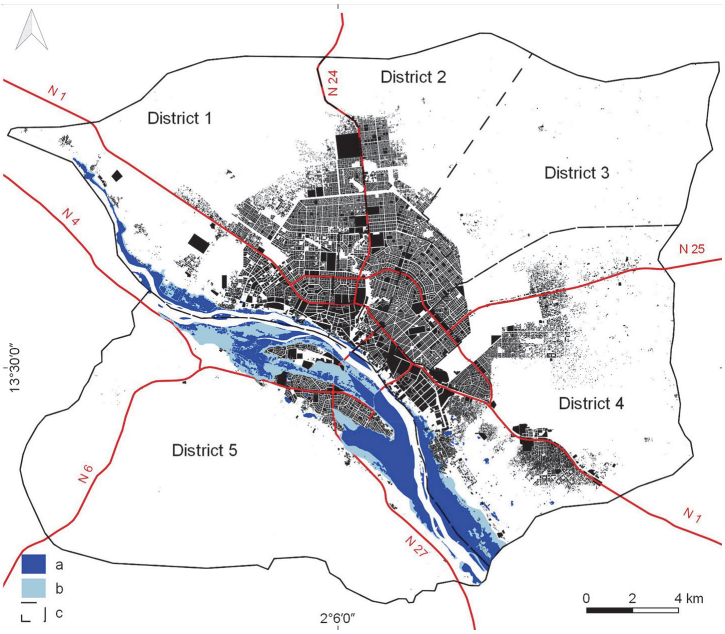

Figure 12.6: Niamey, 2014. Areas prone to river flood with (a) over 1 m water depth, (b) 0–1 m water depth, (c) districts limits, built up areas at 2014 (black) and national roads (red) (by S. Braccio)

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Table 12.1: Niamey, Flood prone areas (by S. Braccio)

Jurisdiction	Flood prone areas due to	Scenario	
		Medium probability of occurrence Ha	High probability of occurrence Ha
Niamey	River flooding > 1 m	1,847	0
	River flooding 0–1 m	1,172	1,847
	River flooding total	3,019	1,847
	Pluvial flooding	–	1,010
Fifth district	River flooding > 1 m	951	0
	River flooding 0–1 m	907	951
	River flooding total	1,858	951
	Pluvial flooding	–	485

rather than distributing them across many different sites, as would be the case in Luanda (15 sites), Maputo (11 sites), Dar es Salaam (7 sites), Nouakchott (5 sites).

In the fifth district, 4.8 km^2 have a high probability of being flooded after heavy rains. Regarding the river flood, 18.6 km^2 have a medium probability of being flooded and 9.5 km^2 have a high probability of being flooded (Table 12.1).

12.5 Damages

Today, the river flood prone areas in the fifth district are mainly cultivated (49%), unused or little used (38%), and to a lesser extent, built-up (13%). The cultivated parts include irrigated crops (paddy, gardens) and rain-fed crops (millet).

The unused or little used parts include barren land, road side slopes, ponds, or receptors for which the damage is difficult to estimate (groves, pastures).

The built-up part of the fifth district includes plots not yet constructed, which, in the event of pluvial flood, are exposed to erosion and damage to the enclosure wall. Then, there are over 8,000 one floor houses, 67% in durable materials and 33% in adobe. There are also schools which, if flooded, risk losing their function as the initial reception for victims, or simply remain unusable if the classrooms consist of wooden shacks (Figure 12.7).

Although the area was devastated by the flood of 22 August 2012 and by that of 30 August 2013, the reconstruction was rapid. Occasionally, the homes were rebuilt in adobe, an inexpensive material not resistant to water, sometimes on a reinforced

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Figure 12.7: Niamey, fifth district, 2013. A selection of receptors: gardens (top left), classrooms in wooden shacks (top right), incremental adobe housing (bottom left), river banks (bottom right) (pictures by S. Braccio and M. Tiepolo)

concrete slab. The stubbornness to remain in the same flood prone site is explained by the lack of alternatives at such a short distance from the downtown (just 4–6 kilometres from the Big market).

Moving to the suburbs, in search of a new plot, would involve huge expenditure and a distance of over 10 kilometres from the downtown.

In the fifth district, according to the high probability scenario, the river flood prone area was 951 hectares and is essentially occupied by fields. The potential damage was in the order of 1.2 million Euros.

According to the medium probability scenario, there were total hectares of 1,858 including 1,832 which were fields and 26 which were built-up where there were just over 8,000 buildings (Table 12.2). The potential damage was 1.4 million Euros for the crops and 40 million Euros for the buildings making a total of 41.4 million Euros.

According to the high probability scenario, the pluvial flood covers a much smaller surface area (485 hectares) and mainly affects the fields, while only two hectares were covered by buildings (Table 12.2). The damage was concentrated only on buildings in adobe and not on those in durable materials or the crops. The poten-

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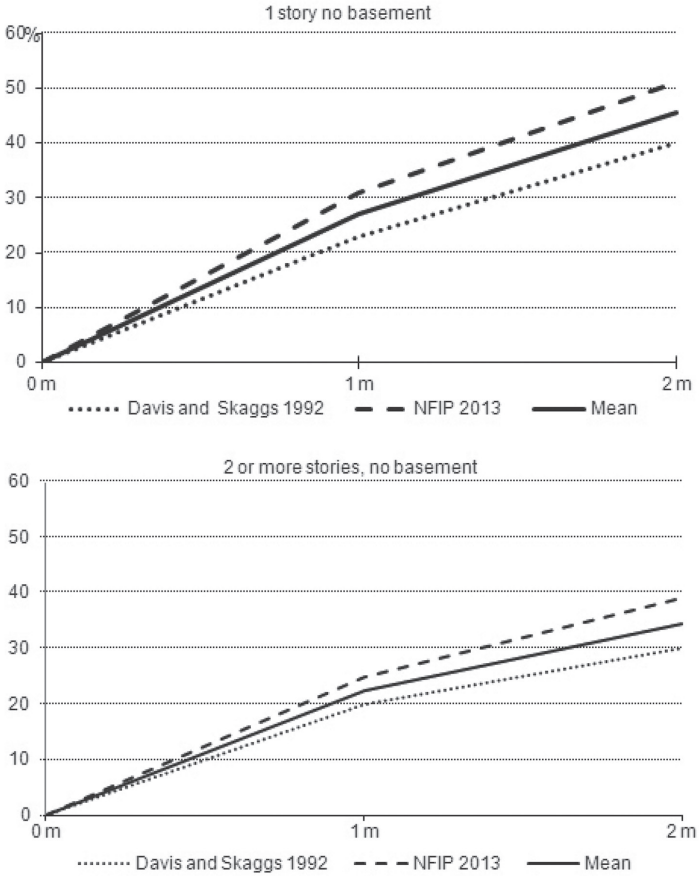

Figure 12.8: Curve stage-damage for buildings with one floor and no basement (a) and two or more floors and no basement (b) in durable materials and the mean considered for this study (source: Davis and Skaggs 1992; NFIP 2013)

tial damage due to collapse or flood of residences in adobe could be estimated at 1.1 million Euros (Table 12.2).

12.6 Risk

The risk is based upon the hazard and the damage: $R = H * D$; where $H = 1/\mathrm{RP}$ (inverse of the return period), D = damage based upon flood depth, building materials and number of floors.

The hazard (1/RP) varies from 0.01 (medium probability of river flood) to 0.34 (high probability of pluvial flood) and influences the value of the risk less the damage, which varies from 0.23 to 1. The housing stock in adobe greatly affects the value of the

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Table 12.2: Niamey, fifth district, 2015. River flood damage according the 2 scenarios.

Scenario Receptor	m²	€/m²	Total M €	D %	D M €	H	R
Pluvial probable							
Housing concrete	12,049	519	6.25	0	0	0.34	0
Housing adobe	5,934	191	1.13	100	1.13	0.34	0.38
Paddy	3,320,167	0.23	0.76	0	0	0.34	0
Millet	1,013,579	0.03	0.03	0	0	0.34	0
Barren, pasture		0		0	0	0.34	0
Total pluvial probable	4,492,772				1.13	0.34	0.038
River probable 0–1 m							
Housing concrete	648	519	0.34	27	0.09	0.1	0.01
Housing adobe	0	191	0	100	0	0.1	0
Other buildings	376	519	0.20	23	0.04	0.1	0
Plots and streets	39,272	0	0	0	0	0.1	0
Paddy, gardens	4,529,298	0.23	1.04	100	1.04	0.1	0.1
Millet	1,429,565	0.03	0.04	100	0.04	0.1	0
Barren, pasture	3,511,936	0	0	100	0	0.1	0
Total river probable	9,511,095		1.61		1.21	0.1	0.12
River middle 0–1 m							
Housing concrete	150,622	519	78.17	27	21.11	0.01	0.21
Housing adobe	74,894	191	14.30	100	14.30	0.01	0.14
Other buildings	38,396	519	19.93	23	4.58	0.01	0.05
Plots, streets	1,987,117	0	0	100	0	0.01	0
Paddy	265,862	0.23	0.06	100	0.06	0.01	0
Millet	2,977,458	0.03	0.08	100	0	0.01	0
Barren, pasture	3,573,159	0	0	100	0	0.01	0
Total	9,067,510		112.47		40.06	0.01	0.40
River middle > 1 m							
Housing concrete	648	519	0.34	46	0.15	0.01	0
Housing adobe	0	191	0	100	0	0.01	0
Other buildings	376	519	0.20	35	0.07	0.01	0
Plots and streets	39,272	0	0	0	0	0.01	0
Paddy	4,529,298	0.23	1.04	100	1.04	0.01	0.01
Millet	1,429,565	0.03	0.04	100	0.04	0.01	0
Barren, pasture	3,511,936	0	0	100	0	0.01	0
Total	9,511,095		1.61		1.30	0.01	0.01
Total river middle			114.08		41.36		0.41

risk, despite constituting only one third of the total stock and being worth just 37% of the equivalent stock (by surface area and number of floors) in durable materials. The fact is that buildings in adobe, if flooded, collapse within a few minutes. This is what

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leads to the potential damage of 100% (1) while for buildings in durable materials, the potential damage never exceeds 47%. Therefore, the pluvial floods seem hazardous only for buildings in adobe and not for other constructions or for crops.

Conversely, the river flood is always disastrous for buildings in adobe and for crops.

Areas with a medium probability of river flood presented the highest overall risk value, followed by those with high probability of river flood and, finally, those with high probability of pluvial flood (Table 12.2).

In the fifth district, the biggest risk (hot spots) was concentrated in four areas (Figure 12.9) which overall measure just twenty-six hectares and present a potential damage of 40 million Euros.

In Niamey the building process is hectic due to rural-urban land use conversion, the increase of density in built-up areas, and continuous increase of prices of construction materials. Consequently, the value of recipients of damage change, even though buildings will always be worth more than crops by unit of surface area and on the total of the exposed receptors. As receptors change over time, the preliminary flood risk map changes. Maps should therefore be understood as a graphic expression of an information system to be kept regularly updated.

12.7 Use of the Preliminary Flood Risk Map

The preliminary flood risk map is based upon the estimate of the construction costs (buildings) or on the sale price (crops) of the receptors and the flood probability: information that is essential in decision making.

The flood adaptation measures are positioned between two extremes: resettlement of inhabitants and activities and the protection of buildings. The receptors in the fifth district alone have (2013) an estimated cost of 114 million Euros including 113 million for the building cost.

The resettlement of inhabitants cannot be limited to finding 8,000 plots in a non-peripheral area. It is also necessary to provide a home (or a core of a home), drinking water, storm water drainage and electricity mains, otherwise people will not move or, if they do, it will only be temporarily. The costs of resettlement thus amount to a minimum of 113 million Euros, plus infrastructures and the purchase of land. This is a significant sum for a city that in 2012 had revenues for investments of just 9 million Euros (RN, VN 2013). It would also then be necessary for there to be a condition that the local government currently does not possess: an iron grip on illegal buildings, to prevent them reoccupying flood prone areas after resettlement.

On the other hand, it is worth constructing and strenghtening embankments for 15.5 km to protect the hot spots in flood prone areas, leaving only the fields exposed to flood, provided that this costs less than the presumed damages to the existing buildings (40 million Euros, in other words 2,581 euro/ml).

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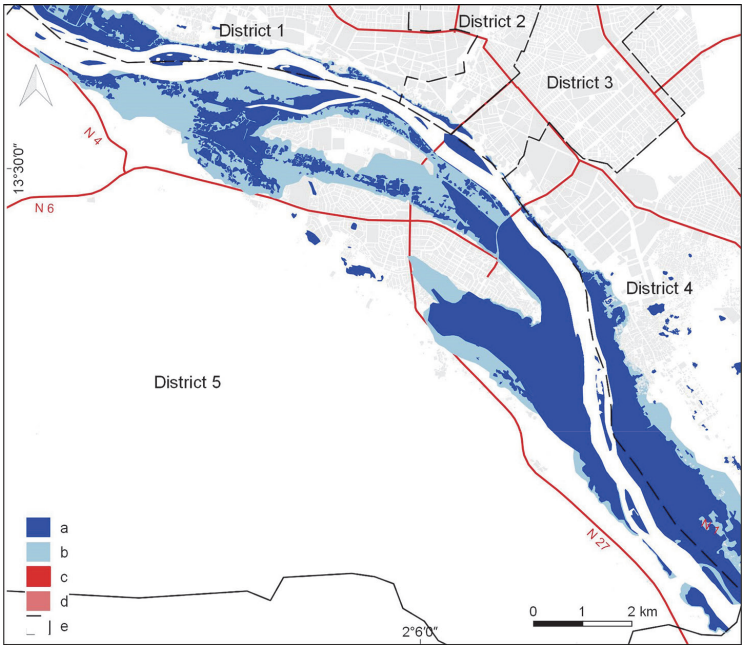

Figure 12.9: Niamey, fifth district, 2014. Preliminary river flood risk map: (a) over 1 m water depth, (b) 0-1 m water depth, (c) flooded houses in over 1 m waters, (d) flooded houses in 0-1 m waters, (e) district limits and built up areas (grey) and national roads (red) (by S. Braccio)

A number of intermediate measures are, of course, possible. They range from the early warning, to emergency plans, to preparedness, to raised entrances, to elevated latrines, etc. (Tiepolo 2014b).

The estimate proposed here is, at present, the best possible within the snapshot tools: the flood prone area, the receptors, their value can be estimated more accurately by way of the following, in order of importance: a more sophisticated Digital Elevation Model (DEM), the production of a curve stage-damage referring to the case of Niamey, the estimate of the impact of runoff-damage, updates of the potential damage based upon the Information system on agricultural markets and the prices index. It remains true that, in any information system, it is necessary to start with an embryo to be expanded later. This was the objective of this chapter.

12.8 Conclusions

From 2008 to date, the regime of the River Niger in Niamey has changed. The alternation of local (red) floods (less important) in August to black floods (annual peak) between January and February, as we have known since the end of the century, inverted in 2010, 2012 (flood peak of the last 69 years) and 2013.

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The red flood is generated by particularly intense rainfall in a vast region upstream of the capital which includes south-east Burkina Faso, crossed by the major tributaries of the River Niger (Sirba, Gorouol, Dargol).

In the 34 years preceding 22 August 2012, the river at Niamey had been silent: it had never exceeded 1,940 m^3/s of discharge (544 cm at the river gauge). In the meantime, the built-up area had grown from 43 to 123 km^2, also occupying the flood plain on the right bank. The flood of 2012 (617 cm at the river gauge) "broke up" 5,533 adobe houses and flooded a further 3,324 in durable materials, producing 44,713 displaced persons on the right bank alone (RN, VN 2012).

The new regime of the River Niger at Niamey also affects the rain-fed cultures (millet) and irrigated cultures (paddy, gardens). At the time, in August, the floodplain on the right bank was dry, the rain-fed crops were maturing and the rice seedlings were being transplanted in the paddy fields of the ONAHA protected by embankments. The peak of 22 August 2012 flooded these areas and the water remained enough to destroying the crops.

Pluvial floods are responsible for lesser damages: there are few areas in which pluvial water stagnates and, for the most part, they are not inhabited.

However, Niamey has reached a critical threshold: almost all flat land, free from risks, is built-up or parcelled out. If the built-up surface area of the capital continues to grow by 50% even in the coming decade – and this will depend upon the demographic dynamic and the need to invest the oil revenue – it will move even further into the flood prone areas, being those costing less and the nearest to the downtown. The first signs are already visible on the sites flooded on 22 August 2012, where at least 20% of the houses seemed to be rebuilt.

Today, in the fifth district (where over half of all the capital's receptors are present) there are 26 hectares of buildings with a medium probability of being flooded with presumed damage of 40 million Euros. The maximum concentration of receptors is in the districts of Lamordé, Karadjie, and Kirkissoye (hot spots). One-third of homes are made from adobe. The areas are delimited: they could be protected with 15.5 km of embankments. They are also close to the downtown, which could make the protection a priority over resettlement, if the intention is to ensure that most of the people should live close to the downtown, reducing commuting and GHG emissions. In addition, protection costs a third of resettlement.

The preliminary flood risk map is the graphic expression of a GIS. Three improvements would be recommended to the work performed up until now:

- More accurate damage assessment. DEM with a high geometric resolution, less than or equal to 1 m and curve stage-damage ascertained for the specific context of Niamey.
- Enhance the pluvial flood scenario. By selecting and analysing satellite imagery in correspondence with the rains with medium probability of occurring, a more accurate perimeter of the flood prone areas could be defined.

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– A study on run-off prone areas. The extension of those areas is significant, albeit not yet very built-up. However, these areas are now parcelled up: today's city and that of tomorrow is being extended to them. These are therefore the hot spots of the coming years on which Niamey municipality should focus its preventive actions to reduce the pluvial flood risk.

The preliminary flood risk map presents two useful cases:

First, it demonstrates the potential of flood risk mapping by way of free sources of information and a GIS that can be used by the local administration;

Second, it is an aid to decision-making, not so much to block the extension of construction in the risk sectors, as intended by Bechler-Carmaux *et al* (2000), but, rather, to localise the adaptation priority measures in the short and medium-term: early warning, public awareness and preparedness, local physical planning, emergency planning, raised entrances, elevated latrines, resettlement or building and strengthening river embankments.

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