Flood risk assessment at municipal level in the Tillabéri region, Niger

Maurizio Tiepolo[34] and Sarah Braccio[35]

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Abstract: The Tillabéri region (population 2.7 million, 97,250 km^2) is the hinterland of the Niger's capital city and the second most susceptible region to flooding in the country, with 416 settlements hit from 2008 to 2013. This chapter aims to present the potential benefits of flood risk assessment at the municipal scale, a tool that can help local authorities in disaster risk reduction. Risk (R) is considered a function of Hazard (H), Exposure (E) and Damages (D) according the equation R = H * E * D. Risk is measured using six indicators. The probability of rain causing settlement flooding each year is measured for each municipality using daily rainfall from meteorological stations (1981-2010) and three-hourly Tropical Rainfall Measuring Mission (TRMM), datasets by NOAA (1998-2011). Settlements flooded (E), people affected, homes destroyed, fields flooded and livestock killed (D) are sourced from Niger's early warning system and disaster prevention unit (EWS DP), all errors corrected and units of measurement standardised. From the results, it emerged that 765 settlements were flooded between 1998 and 2013. Contrary to what one might expect, the floods caused by the swelling of the River Niger hit few settlements. Most of the areas susceptible to flooding were located in the vast Bosso and Maouri dallols, two fossil rivers that run from Mali towards Niger for over 300 km. The right-bank tributaries of the Niger and along the minor hydrographic network were the next most affected areas. Ninety-five settlements were hit more than once and 19 flooded in two or more consecutive years. Seven municipalities out of 41 were at very high or high risk of being flooded. These are crossed by the River Niger or by its main tributaries on the right bank, by the Ouallam intermittent creek or the Bosso dallol. Seven municipalities showed damage in three areas (people, dwellings, fields).

Keywords: Damages, Exposure, Hazard, Local development plan, Risk.

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13.1 Introduction

The Tillabéri region (2.7 million inhabitants, 97,250 km^2) is the vast rural hinterland and main migration basin of the Niger capital city, Niamey (1.1 million inhabitants in 2012). Between 2008 and 2013, 416 settlements of the Tillabéri region were flooded, ranking the region amongst those most affected by the disaster in the country. The range of the impact had many causes: climate change over recent years, the presence of a vast hydrographic basin (Figure 13.1), and insufficient disaster risk reduction (DRR) measures developed by municipalities. Prevention and adaptation require coordinated commitment by both central and local structures – the latter being nearest to the affected populations. If the State were to fund municipalities for DRR, a municipal level flood risk assessment could become a useful tool in decision-making.

This chapter aims to test, on the Tillabéri region, the potential of a snap shot flood risk assessment at the municipal level, updatable within the national early warning system and disaster prevention unit (EWS DP).

The Tillabéri region is divided, according the 2006 administrative subdivision (RN, MEF INS 2006), into 44 municipalities (Figure 13.2). These are vast (often more than 2,200 km^2) administrative units which often contain more than one hundred of settlements. Three municipalities were lacking of some information thus were not considered in our assessment. Our flood risk assessment did not take into account the specifics of the various settlements within each municipality.

Risk (R) is «the combination of the probability of an event and its negative consequences» (UNISDR 2009: 25). This may be calculated in various ways (Tiepolo 2014): for example, using the equation R = (H * E * V) / A (Gotangco *et al* 2010) where hazard (H) is the probability of the event at the source of flooding (rain); exposure (E) is the property that may be damaged or lost following flooding; vulnerability (V) is the weakness that may amplify the effect of the flooding and adaptation (A) covers all the measures used to reduce impact. With the exception of hazard, the other three flood risk components can be calculated in two ways:

a) by measuring the factors that are presumed to determine the value of each component (Ponte 2014), for example poverty, population density, adaptation measures, etc.
b) by measuring the effect of the components in terms of damages and losses presumed (ECHO, UNDP 2008; CDEMA 2009; Marzocchi *et al* 2009; Sayers *et al* 2010) or having occurred in the past, being damage (D) the «total or partial destruction of physical assets existing in the affected area» (World Bank 2010: 2).

Which of the two ways is chosen depends on the aims of the risk assessment, on the extension of the territory on which it is calculated and on the information, methods and time available.

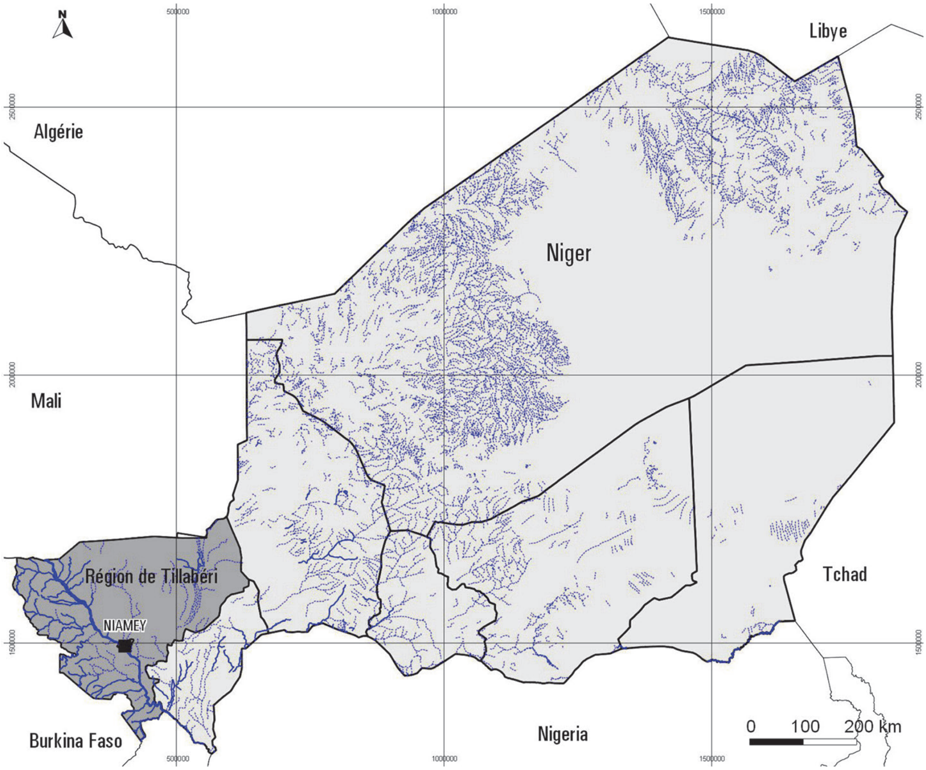

Figure 13.1: Tillabéri (dark grey) and the other regions of Niger (thick line) with the hydrographic network (blue)

The first way requires detailed information that allows the value of the E, V and A components to be appraised. Usually this approach is used for territories of limited extension, like a city (Holloway *et al* 2010; Ponte 2014) or a district, or more specifically over a few hundred or few thousand km^2.

In Niger, there is currently no information available to calculate E, V and A on a municipal level. Therefore, we chose the second way. We should discard any specific collection of information if we wish to build a sustainable risk assessment. Instead, we should rely on regular collections of information that have already been active and tested. We can appraise a hazard by using the data collected regularly from the National Directorate of Meteorology (DMN according to the French acronym) through the pluviometric station network and that recorded by satellite. The EWS DP database (DB) in the prime minister's office has held records of flooding dates since 1998, settlements flooded, the number of people affected, the number of houses destroyed, fields flooded and livestock lost as well as other occasional or heterogeneously-quantified damage to equipment and infrastructure.

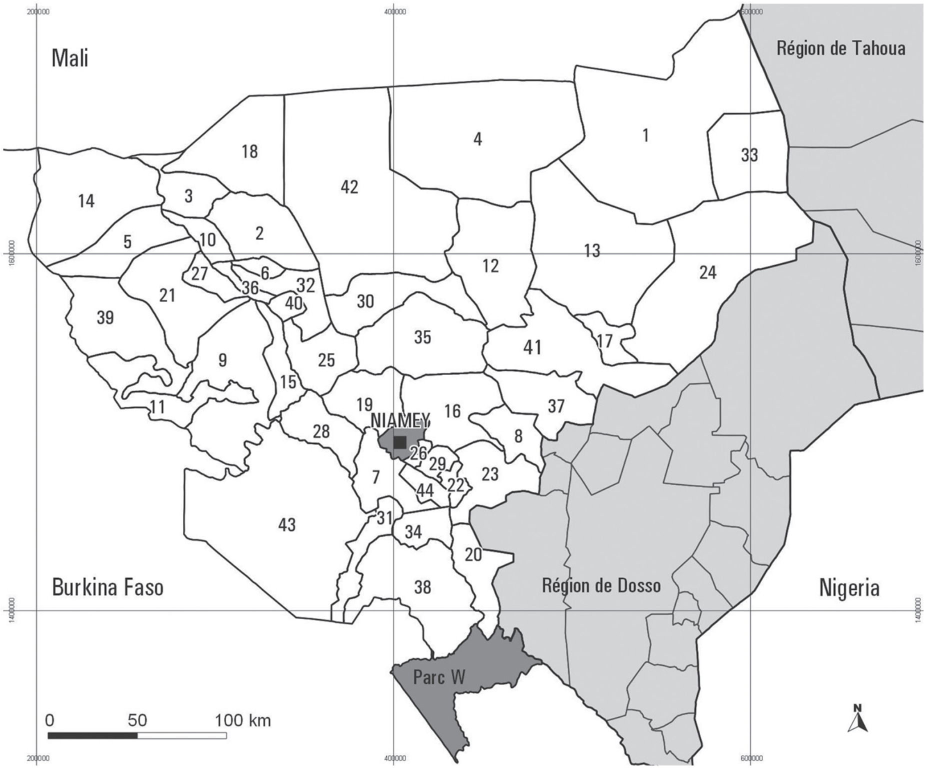

Figure 13.2: Tillabéri region, 2006. Subdivision into 44 municipalities: 1 Abala, 2 Anzourou, 3 Ayerou, 4 Banibangou, 5 Bankilaré, 6 Bibiyergou, 7 Bitinkodji, 8 Dantchandou, 9 Dargol, 10 Dessa, 11 Diagourou, 12 Dingazi, 13 Filingué, 14 Goroual, 15 Gothèye, 16 Hamdallaye, 17 Imanan, 18 Inates, 19 Karma, 20 Kirtachi, 21 Kokorou, 22 Kollo, 23 Kouré, 24 Kourfeye, 25 Kourteye, 26 Liboré, 27 Mehana, 28 Namaro, 29 N'Dounga, 30 Ouallam, 31 Ouro Gueledjo, 32 Sakoira, 33 Sanam, 34 Say, 35 Simiri, 36 Sinder, 37 Tagazar, 38 Tamou, 39 Téra, 40 Tillabéri, 41 Tondikandia, 42 Tondikiwindi, 43 Torodi, 44 Youri.

Consequently, hazard (H) in each municipality may be calculated as the inverse return period of the (critical) minimal rainfall presumed responsible for disastrous flooding over the past 16 years. The daily pluviometric values recorded at 14 meteorological stations by DMN (1981–2012) and the three-hourly data sets (1988–2011) as available with Ncview allowed Bacci (2016, chapter 5) to identify the rainfall responsible for flooding and how often it recurred.

Exposure (E) was expressed through flooded settlements (having registered some damage). Using a 16-year long series of data, we can assume that each municipality has already been subject to many types of rain (very heavy, heavy, out of season) and, therefore, that many flood-prone settlements have been flooded–including those resulting from the recent conversion into built-up sites.

Damage (D) was expressed through victims, dwellings collapsed, fields flooded, livestock killed during the last 16 years as registered by the EWS DP DB.

Each risk component was measured through indicators that are not weighed:

$$R = H_{1981\text{–}2011} * (E_{1998\text{–}2013} * Damages_{1998\text{–}2013})$$
$$= 1/Return\ period * Flooded\ settlements * (Victims + Houses + Fields + Livestock)$$

The following equation can be applied to municipality x:

$$R\ municipality\ x = 1/RP * (s/p * P/S) * [(v/p * P/V) + (h/p * P/H) + (f/p * P/F) + (b/p * P/B)]$$

where:
l = dead livestock$_{1998\text{–}2013}$ in municipality x
L = dead livestock$_{1998\text{–}2013}$ in the Tillabéri region
f = flooded fields$_{1998\text{–}2013}$ in municipality x
F = flooded fields$_{1998\text{–}2013}$ in the Tillabéri region
s = flooded settlements$_{1998\text{–}2013}$ in municipality x
S = flooded settlements$_{1998\text{–}2013}$ in the Tillabéri region
h = collapsed houses$_{1998\text{–}2013}$ in municipality x
H = collapsed houses$_{1998\text{–}2013}$ in the Tillabéri region
p = population $_{2001}$ of municipality x
P = population $_{2001}$ of the Tillabéri region
RP = return period of critic rain
v = victims$_{1998\text{–}2013}$ in municipality x
V = victims$_{1998\text{–}2013}$ in the Tillabéri region

In order to calculate damage to fields recorded with different units of measurement (number and surface) and to appraise the significance of the loss of dwellings and livestock of which no consistency is known on the municipal scale, the rate of such damage in each municipality was calculated in relation to damage of the same type within the region. Therefore, the municipality population rate was calculated with respect to the regional one of 2001[37]. Then, the first rate was compared to the second.

The severity of damage was, therefore, calculated compared to the municipality's demographic importance within its region.

There is also a practical reason for this choice. The State transfers funds to municipalities according their demographic size. Local taxation yield in rural municipalities is coming mainly from commercial activities that are proportionate to the number of inhabitants. When damage greatly exceeds the demographic weight of a municipality, local governments will have fewer means for DRR and post-flooding interventions.

37 The 2012 census data on municipal population are not published yet.

The method measures each component of risk consistently and thereby shows the H, E and D contribution to the risk value.

The EWS DP DB cannot be directly used for our purposes. First, checking the name of each flooded settlement is necessary: the slightest change in how the name is written would impede the flooded settlements being localised. To this end, we have referred to settlement names as supplied by the national repository of municipalities (RN, MEF, INS-Niger 2006).

Second, dividing the damage where the EWS DP DB attributes it to more than one settlement. In this case, we simply divided the damage by the number of settlements to which it was assigned. The approach may seem too simple, but it is justified by the often modest quantity of said damage. Other methods, for example based on the demographic size of the settlements, would have caused fractions of damage (e.g., half a cow, half a dwelling, etc.) to be attributed to the smallest villages.

Thirdly, we found very high damage values that may have come from transcription errors. In these cases, the damage (e.g., number of collapsed houses that largely encompass the number of flooded settlements households) was not considered.

Fourth, the flooded fields registered were sometimes reported as a number, and sometimes as hectares. We converted all registrations in hectares assuming that in Tillabéri region a field is on average 3.43 Ha, as found in the municipality of Téra (RN, RT, DT, CUT 2009: 21). Should a variety of animals be lost, we used the unit of tropical livestock (UBT following the French acronym): camels 1 UBT, horses 0.8, bovines 0.7, donkeys 0.5, sheep and goats 0.1, poultry and swine 0.01 (Jahnke 1982).

In the following pages, we will present (ii) hazard, (iii) exposure, (iv) damage, (v) risk, (vi) use of flood risk assessment in local development planning, (vii) conclusions.

13.2 Hazard

Hazard (H) is «a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihood and services, social and economic disruption, or environmental damage» (UNISDR 2009: 17).

The municipalities of the Tillabéri Region can be characterised by a dominant watershed: River Niger and primary tributaries, River Niger, primary tributaries, secondary tributaries, Dallols (fossil rivers). For each dominant watershed, the critical rainfall generating the flood can be identified considering that the concentration time (the time needed for water to flow from the most remote point in the watershed to the watershed outlet) is hours for secondary tributaries of fossil rivers (dallols), and days for primary tributaries.

EWS DB reports the dates of 110 floods from 2006 to 2012.

Two sets of data were used by Bacci (2016, chapter 5) for rainfall appreciation: daily rainfall for primary tributaries floods, as registered at 14 meteorological stations by DMN, and 3-hourly rainfall for secondary tributaries or fossil rivers (dallols) as from TRMM (1998–2011) at the grid point on the centroid of the municipality. Rainfall was collected in the 5 days around each flood date. Only the maximum value was retained. Once the rain was associated with the flood, it was time to determine the critical rain. From 2006 to 2012, some municipalities were flooded only once, while others were flooded several times (up to 13 times). In the case of multiple floods, the lowest value of rain was selected as the critical rain (Table 13.1).

Then the probability of having a similar rain was calculated per Bacci (2016) as the inverse of the return period on the series of rainfall 1981–2010 in 14 meteorological stations. Municipalities with no meteorological station were considered to have received the same rain as the nearest upriver municipality with the same hydrographical conditions (Table 13.1).

Figure 13.3: Niger, June 2014. The River Niger around Namaro (left) and the Sirba river (right) close to the confluence in the River Niger (photo M. Tiepolo)

13.3 Exposure

Exposure refers to «people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses» (UNISDR 2009: 15).

Firstly, we should remember that three characteristics refer to the Tillabéri region regarding the flooding events of the last six years:

1. it is the second most affected region in Niger after Dosso (Table 13.1);
2. it ranks second (after Agadez and Dosso) for magnitude of flooded settlements compared to its demographic proportion of the national total (Table 13.2);
3. every year the number of flooded settlements is relevant, while Dosso, Zinder and Agadez have had years with peaks followed by years without disaster (Figure 13.4).

Table 13.1: Tillabéri region. Critical rain for each municipality (Bacci 2016, chapter 5).

Municipality	Type of critical rain D = daily, 3-h = 3-hours	Critical rain mm
Abala	3h	79.6
Anzourou	3h	73.4
Ayerou	D	73.4
Bani Bangou	3h	79.6
Bankilaré	D	61.8
Bibiyergou	3h	75.2
Bitinkodji	D	61.7
Dargol	D	75.2
Dessa	D	73.4
Diagorou	D	75.2
Diantchandou	3h	51
Dingazi Banda	3h	51
Filingué	3h	42.5
Gorouol	D	66
Gothèye	D	66
Hamdallaye	D	30
Imanan	3h	45
Inates	D	73.4
Karma	D	54
Kirtachi	D	75.5
Kokorou	D	61.8
Kollo	D	75.5
Kouré	D	75.5
Kourfey	3h	40
Kourtey	D	72.8
Liboré	D	61.7
Méhana	D	72.8
Namaro	D	58
N'Dounga	D	61.7
Ouallam	3h	36
Ouro Gueladjio	D	75.2
Sakoira	D	86.3
Sanam	3h	113.9
Say	D	75.5
Simiri	3h	70
Sinder	D	72.8
Tagazar	3h	51
Tamou	D	75.5
Téra	D	52
Tillabéri	D	75.2
Tondikandia	3h	59
Tondikiwindi	3h	36
Torodi	D	75.2
Youri	D	75.5

Table 13.2: Regions of the Niger, 2008–2013. Settlements flooded, demographic weight (sources: RN, SAP 2008–2013; RN, MF, INS 2012)

Region	Flooded settlements No.	P_{2012} No.	Flooded settlements %	P_{2012} %	Δ L-P Times
Agadez	163	481,982	8	3	2.67
Diffa	47	591,788	2	3	−0.67
Dosso	617	2,040,699	32	12	2.67
Maradi	157	3,404,645	8	20	−0.40
Niamey	39	1,011,277	2	8	−0.25
Tahoua	136	1,972,907	7	11	−0.64
Tillabéri	416	2,715,186	21	16	1.31
Zinder	374	3,556,239	19	21	−0.90
Niger	1,949	17,129,076	100	100	0.00

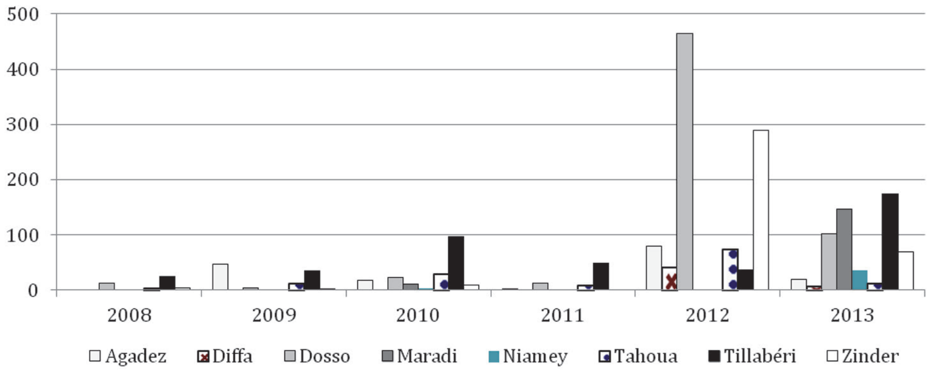

Figure 13.4: Niger, 2008–2013. Number of flooded settlements per region and per year (source: RN, SAP 2009–2013)

Secondly, considering that the smallest unit for analysis is the municipality and that we operated in a vast regional context, exposure was given by the settlements that were effectively flooded over the past 16 years.

The EWS DP's flooding DB (1998–2013) allowed us to identify 765 flooded settlements in the region of which 472 we localised with geographical coordinates (62%).

Over the course of the last eight years, there were peaks in 2006, 2010 and 2013 for number of settlements flooded. The size of these peaks increased over time. Nonetheless, we should warn the reader that this trend does not always correspond with reality – especially for the period prior to 2008, when the floods were not registered systematically.

The largest number of flooded settlements was found in the area over a kilometre away from the banks of the River Niger (27%), therefore on sites protected from flooding. These were probably flash floods of secondary tributaries of the great river. The next largest were the Bosso and Maouri dallols, followed by the main tributaries of the right bank (23%) (Table 13.3).

Table 13.3: Tillabéri region, 1998–2012. Settlements flooded by zone.

Zone	Flooded settlements	
	No.	%
River Niger, < 1 km	77	16
River Niger, not coastal	126	27
Right bank		
Main tributaries	107	23
Left bank		
Bosso and Maouri dallols	116	24
Minor tributaries	46	10
Total	472	100

Over the 16 years observed, 95 settlements flooded more than once: or rather, 12% of the settlements flooded in the region (Table 13.4, Figure 13.5). In some municipalities, such as Liboré and Kourfeye, this rate was closer to 30%. Thankfully, most of the repeated flooding affected 10 municipalities (which had three or more settlements affected). These were found along the Bosso dallol, the River Niger, the Sirba and the great Ouallam intermittent creek. The phenomenon is particularly serious when it happens over two consecutive years, because the populations affected don't have the time to bounce back from the first event when a new one hits again. Nineteen settlements were flooded for two or more years, an event that has mainly been found along the Niger River. In half of the cases, it was the capital of the municipality that was hit.

The amount of exposure contributing to risk was calculated by comparing the number of flooded settlements in the municipality to the total of flooded settlements in the region, and comparing this number with that of the demographic weight of the municipality relative to the region, as explained in the equation:

$E\ municipality\ x = s/p * P/S$

where:
p = population of municipality x
P = population of the region
s = flooded settlements in municipality x
S = flooded settlements in the region

Table 13.4: Tillabéri region, 1998–2013. Settlements flooded more than once.

Municipality	Settlements flooded			
	a	b	c	d
	From 2 to 4 years No.	2 consecutive years No.	More years No.	a/c %
Liboré	16	1	17	31
Gotheye	11	1	12	26
Abala	9	0	9	19
Simiri	6	1	7	27
Imanan	5	1	6	23
Tondikiwindi	2	3	5	10
Say	3	1	4	13
Kourfeye	1	2	3	29
Kourteye	3	0	3	9
Tamou	2	1	3	5
Other 18 municipalities	16	10	26	–
Total	75	20	95	12

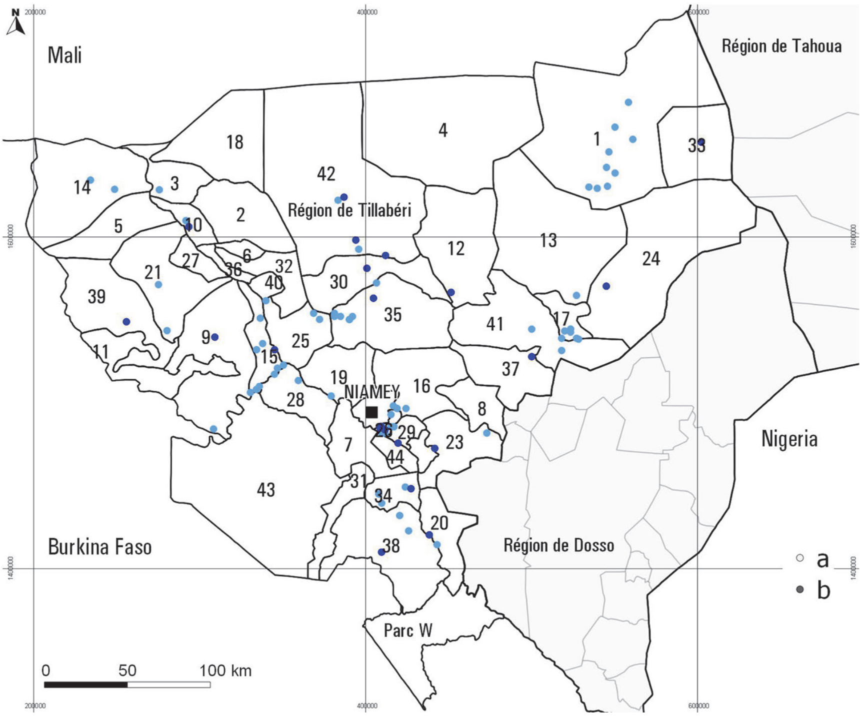

Figure 13.5: Tillabéri region, 1998–2013. Settlements flooded more than once (lift blue), for two consecutive years (blue)

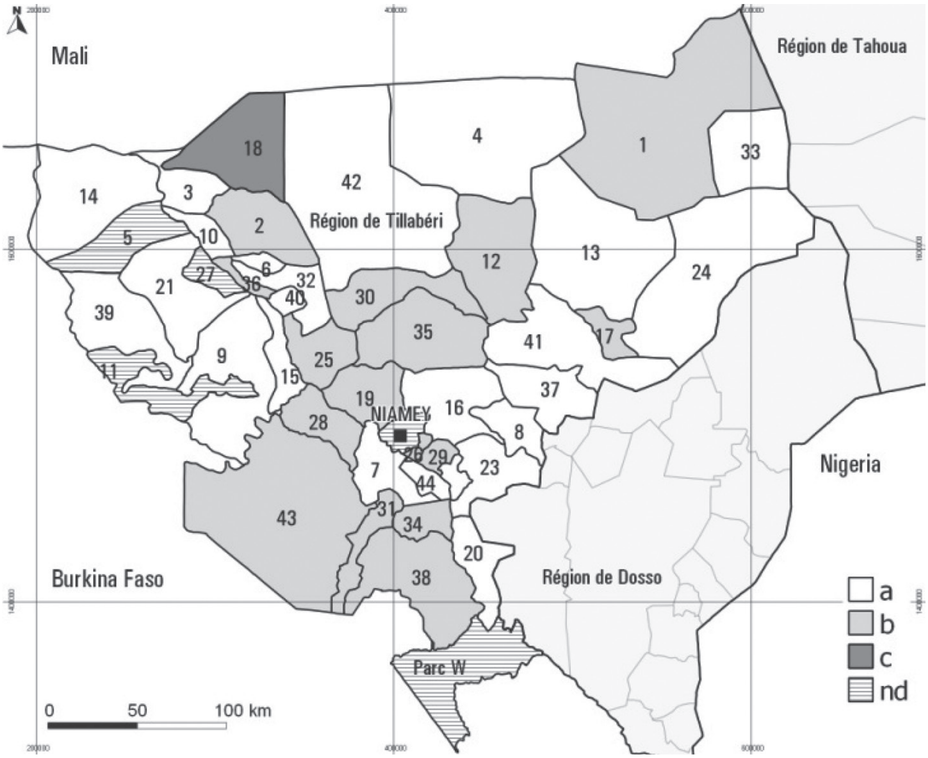

Figure 13.6: Tillabéri region. Exposure: low (a), moderate (b), high (c) (S. Braccio)

The result was that almost half of Tillabéri's municipalities had an exposure of five times their demographic weight relative to that of the whole region (maximum value for Inates). An exposure value equal to the demographic weight was performed by Tillabéri municipality. A little over half of the municipalities showed exposure values less than the respective demographic weights in the region, with Bitinkondji and Youri municipalities ranking last (Table 13.5, Figure 13.6).

13.4 Damage

In Niger, there was insufficient information to measure the factors that determined vulnerability and adaptation on the municipal level, and it was impossible to collect the information on a regular basis. This limit may be overcome if we move our attention onto the effects of vulnerability and adaptation. If a community is poor, badly organised, settled in the valley, located where fields are not protected with dykes, and livestock is not sheltered in protected areas, it is more likely that any flooding

Table 13.5: Tillabéri region. Municipalities ordered by importance of the flood risk.

Municipality	Hazard	Exposure	Damage				Risk
	Indicator 1	Indicator 2	Indicator 3	Indicator 4	Indicator 5	Indicator 6	
	1/Return period	Settlements	Victims	Houses	Fields	Livestock	Time
18 Inates	0.5	5.09	4.8	0.00	0.00	267.7	693.4
29 N'Dounga	1	2.60	5.6	2.4	12.00	0.00	51.9
26 Liboré	1	4.56	3.1	2.4	4.1	0.00	43.9
31 Ouro Gueledjo	1	2.31	0.91	10.01	1.4	0.12	29.0
28 Namaro	1	1.67	5.2	1.3	7.1	0.01	22.7
34 Say	0.22	2.93	2.50	20.9	2.6	0.15	16.9
30 Ouallam	1	2.34	1.50	0.34	2.4	0.63	11.5
42 Tondikiwindi	1	2.56	0.53	0.25	0.62	0.75	5.5
38 Tamou	0.22	2.48	1.5	5.6	1.3	0.10	4.6
12 Dingazi	1	1.86	0.4	0.07	0.88	0.95	4.3
17 Imanan	1	1.32	1.6	0.02	1.4	0.04	4.0
19 Karma	1	1.09	1.3	0.10	0.95	0.00	2.6
14 Goroual	1	0.97	0.88	0.23	1.2	0.01	2.3
22 Kollo	0.22	0.51	7.7	2.0	9.5	0.20	2.2
15 Gothèye	1	0.90	1.3	0.40	0.45	0.00	1.9
16 Hamdallaye	1	0.96	0.76	0.24	0.16	0.00	1.1
36 Sinder	0.33	1.11	1.9	0.00	0.82	0.00	1.0
10 Dessa	0.5	0.97	0.53	0.03	1.4	0.04	1.0
43 Torodi	1	0.81	0.60	0.10	0.46	0.00	0.9
35 Simiri	0.5	1.20	0.59	0.10	0.62	0.17	0.9
4 Banibangou	0.14	0.27	0.09	0.07	0.23	20.2	0.8
32 Sakoira	0.33	0.75	1.3	0.02	1.7	0.00	0.8
8 Dantchandou	1	0.26	2.0	0.23	0.38	0.00	0.7
1 Abala	0.08	1.36	0.72	0.11	0.05	5.2	0.7
41 Tondikandia	1	0.77	0.28	0.02	0.51	0.00	0.6
25 Kourtheye	0.33	1.33	0.81	0.06	0.15	0.01	0.5
7 Bitinkodji	1	0.15	1.5	0.15	1.2	0.00	0.4
20 Kirtachi	0.22	0.18	3.2	2.3	4.3	0.00	0.4
2 Anzourou	0.4	1.08	0.47	0.13	0.12	0.07	0.3
40 Tillabéri	0.33	1.02	0.40	0.17	0.38	0.00	0.3
13 Filingué	1	0.49	0.24	0.08	0.27	0.01	0.3
24 Kourfeye	1	0.24	0.10	0.07	0.73	0.00	0.2
23 Koure	0.22	0.58	1.1	0.13	0.25	0.05	0.2
9 Dargol	1	0.39	0.24	0.14	0.05	0.02	0.2
21 Kokorou	0.5	0.36	0.38	0.11	0.21	0.24	0.2
6 Bibiyergou	0.13	0.98	0.20	0.15	0.37	0.00	0.1
37 Tagazar	1	0.38	0.10	0.00	0.07	0.00	0.1
39 Téra	0.5	0.22	0.00	0.23	0.06	0.15	0.0
44 Youri	0.22	0.15	0.77	0.13	0.49	0.00	0.0
3 Ayerou	0.5	0.17	0.00	0.02	0.13	0.00	0.0
33 Sanam	0.08	0.30	0.19	0.03	0.00	0.00	0.0

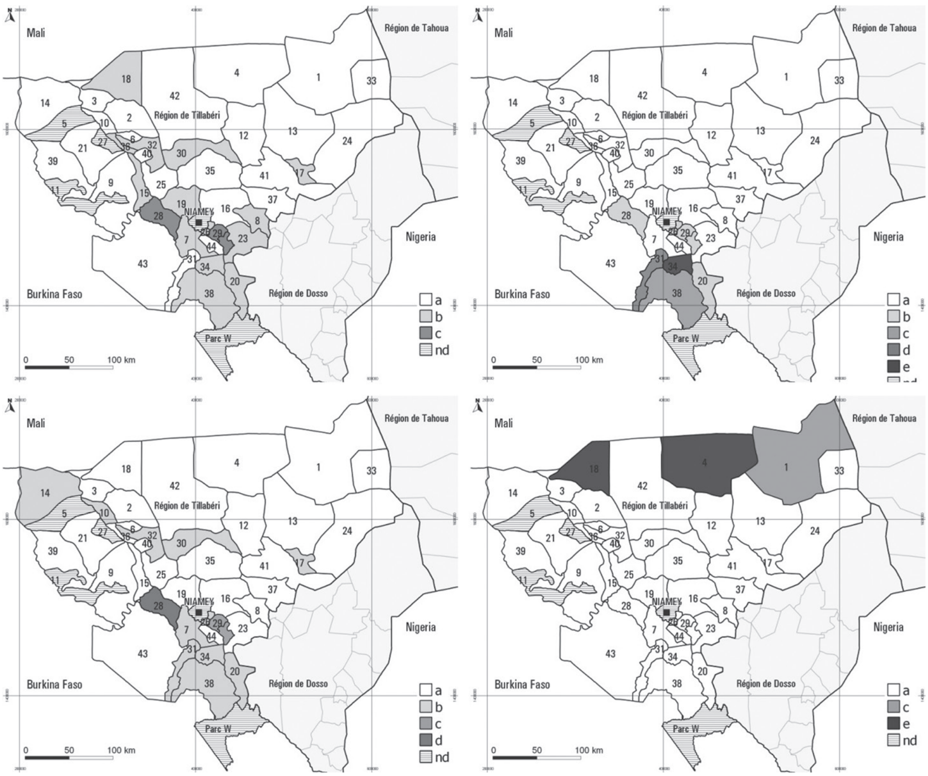

Figure 13.7: Tillabéri region, 1998–2013. Indicators of damage on a municipal scale: victims (high, left), dwellings (high, right), fields (low, left), livestock (low, right). The value classes are: < 0 (a). 0–5 (b), 6–10 (c) higher than 10 (d), data not available (nd) (elaborated by S. Braccio).

will have more widespread and significant effects on the population, dwellings, fields and livestock.

The EWS DP's DB holds four types of information on damage: the amount of population affected (victims), dwellings destroyed, fields flooded and livestock killed. We used the same procedure to obtain the value of each indicator as that for assessing exposure. For example, for indicator 3 (victims) the equation is the following:

*Indicator 3 municipality x = v/p * P/V*

where:
p = population 2001 of municipality x
P = population 2001 of the Tillabéri region
v = victims 1998-2013 in municipality x
V = victims 1998-2013 in the Tillabéri region

As for the results (Table 13.5, Figure 13.7), four elements were considered:

1. The variation field for the values of damage indicators was much higher than we had seen for the exposure indicator: 1,438 to 0 (livestock), 20 to 0.1 (houses), 7 to 0.15 (victims), 11.9 to 0 (fields). Therefore, some municipalities were badly hit by the floodings compared to their demographic weight in the region.
2. Those municipalities with indicator values higher than 1 were in the minority: 19 for victims, 14 for flooded fields, 8 for houses destroyed, 3 for lost livestock over a total of 41 municipalities on which we had data. Luckily, few municipalities were vulnerable or poorly adapted.
3. There were 12 municipalities that had more than one indicator higher than 1: Say, N'Dounga, Kollo, Namaro, Tamou, Kirtachi, Liboré (victims, houses, fields), Say and Tamou (houses, fields), Abala (fields, livestock). This means that large scale vulnerability or non-adaptation only affected a few municipalities.
4. Only three municipalities had a positive livestock indicator (Inates, Abala, Banibangou) and were all in range areas.

13.5 Flood Risk

According to the methodology used, the numeric value of a municipality's risk expresses the number of times damage was recorded between 1998 and 2013 in a given municipality compared to the total damage in the region which may exceed or be less than the municipality's demographic weight in the region in 2001, possibly reduced by hazard, and further reduced or increased by exposure (Table 13.5).

If the R value exceeds 20, the risk is considered very high. If the value is between 11 and 20 the risk is high; between 1 and 10, risk is moderate and if it is less than 1 it is low. Firstly, it should be made clear that the EWS DP DB did not contain any data on the municipalities of Bankilaré, Diagourou and Méhana. For the other 41 municipalities, five were at very high risk of flooding, two were at high risk, 11 at moderate risk and the remaining 23 municipalities were at low risk.

It should be noted that, in the event of flooding, a low risk level does not necessarily mean a municipality is immune to damage. In fact, the risk map (Figure 13.8) only shows which municipalities have suffered less damage than their demographic weight within the region, and in which the damage has been higher or much higher.

The municipalities that are at very high or high risk are, in order: Inates, N'Dounga, Liboré, Ouro-Gueledjio, Namaro, Say and Ouallam.

Luckily, this represents just 17% of the region's municipalities. With the exception of Inates and Ouallam, these municipalities are located along the River Niger or are crossed by its main tributaries. In these cases, risk value was determined by high values of five indicators out of six (Table 13.5) with the sole exception of Inates, which had three extremely high indicators out of six, especially regarding loss of livestock.

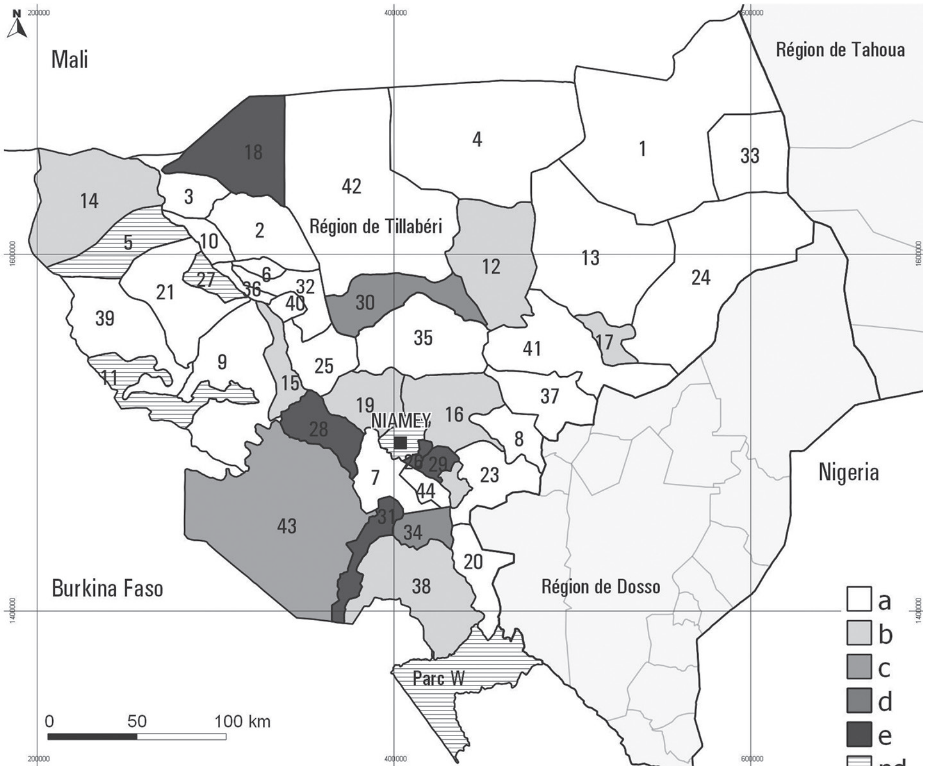

Figure 13.8: Tillabéri region. Flooding risk on the municipal level: low < 1 (a), moderate 1–10 (b), high 11–20 (c), very high > 20 (d)

Municipalities at very high and high risk covered 36% of the region's population. These were mainly medium size municipalities (40,000–80,000 inhabitants) whose chief town is within a 60 km radius of Niamey, with the sole exceptions of Ouallam (93 km) and Inates (more than 200 km). This means we are in the presence of municipalities that are linked to Niamey through asphalted roads, making the materials and the machinery for DRR available in the capital city easy accessible.

The risk components (H, E, D) analysis allowed us to make suggestions to the municipalities in identifying adaptation measures.

Nonetheless, the relationship between risk and indicators was closer for exposure, or rather, how many settlements were flooded in a municipality compared with the total number of settlements flooded in the region. All those at high or very risk were among the nine most exposed municipalities (Table 13.6).

The method used to assess the risk on the municipal level allowed this activity to be conceived as monitoring instead of a one-off measure. It is enough to update hazard, to introduce the new data on damage and exposure. Following monitoring, the position of the municipalities on the risk scale may change.

Table 13.6: Tillabéri Region. Comparison between exposure and risk.

Municipality	Exposure 1 indicator	Risk 6 indicators
Inates	5.09	693.4
Liboré	4.56	43.9
Say	2.93	16.9
N'Dounga	2.60	27.0
Tondikiwindi	2.56	51.9
Tamou	2.48	4.6
Ouallam	2.34	11.5
Ouro Gueledjo	2.31	29.0
Dingazi	1.86	4.3
Namaro	1.67	22.7
Abala	1.36	0.7
Kourtheye	1.33	0.5
Imanan	1.32	4.0
Simiri	1.20	0.9
Sinder	1.11	1.0
Karma	1.09	2.6
Anzourou	1.08	0.3
Tillabéri	1.02	0.3
Bibiyergou	0.98	0.1
Goroual	0.97	2.3
Dessa	0.97	1.0
Hamdallaye	0.96	1.1
Gothèye	0.90	1.9
Torodi	0.81	0.9
Tondikandia	0.77	0.6
Sakoira	0.75	0.8
Koure	0.58	0.2
Kollo	0.51	2.2
Filingué	0.49	0.3
Dargol	0.39	0.2
Tagazar	0.38	0.1
Kokorou	0.36	0.2
Sanam	0.30	0.0
Banibangou	0.27	0.8
Dantchandou	0.26	0.7
Kourfeye	0.24	0.2
Téra	0.22	0.0
Kirtachi	0.18	0.4
Ayerou	0.17	0.0
Bitinkodji	0.15	0.4
Youri	0.15	0.0

13.6 Use of Flood Risk Assessment for Local Planning

In 2012, the National council for the environment and sustainable development (CNEDD according the French acronym) started to promote adaptation to climate change in the Municipal development plans (MDPs). To this end, we should remember that only nine of the 44 municipalities in the Tillabéri region had started to or completed the DRR integration in their MDP so far.

Adaptation to climate change involves analysing the main hazards to which the municipality is exposed and planning DRR measures. Hazard analysis has been rather concise in the MDPs adapted so far: the trend of annual precipitations and how much time passes between rainfalls were analysed, but the recurrence of intense rainfall was not considered, nor was the discharge of the River Niger for the municipalities it crosses. Drought was not analysed through the SPI, nor was it analysed considering how much water is required for the main cultivations. Finally, flood prone settlements were not identified.

The risk assessment developed in this chapter may contribute to improving the MDPs' adaptation to climate change. In fact, settlements frequently flooded over the past 16 years (Figure 13.5) may be compared with measures provided by the MDP. Based on the measures provided for each settlement by MDPs, we can confirm that, still today, just one sixth of those settlements that flooded between 1998 and 2013 are subject to some adaptation measures. These measures are, in order of frequency, mini dams, stone cords, trapezoidal bunds, contour stone bunds, semi circular bunds, weirs, zai, restoration of wells, treatment of water course banks, protection dykes, sensitisation, planting, etc. (Critchely *et al* 1991).

Therefore, the vast majority of the flooded settlements are not subjected to any DRR measures by the MDP.

Starting from these sites and the hydrographical network, a preliminary map of the flood prone areas can be prepared for the most exposed river sectors. It could aid adaptation decision making.

13.7 Uncertainties in Input Data and Resulting Outcomes

The main sources on which the risk assessment at municipal scale was based are the EWS DP DB (damage), the meteorological stations records and the TRMM records (rain), and the national population census (population). There were no gaps in time regarding the daily precipitation (1981–2010), the 3-hourly precipitation (1998–2011) or the damage (2005–2013). Gaps in space existed for daily precipitation, which were collected by 14 meteorological stations for 44 municipalities.

Errors were limited to EWS DP DB and regarded the names of the settlements flooded and the amount of damage. These errors were often due to transcription and

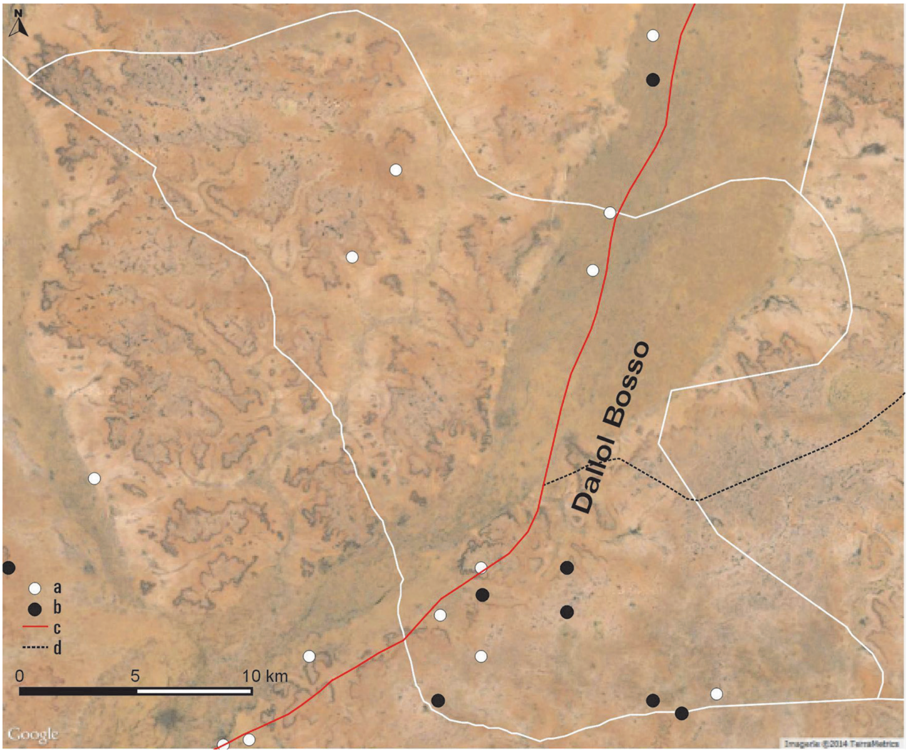

Figure 13.9: Imanan municipality, 2013. Settlements flooded once (a), twice or more (b), paved road (c), dirty road (d). Some flooded localities are just in the middle of the dallol (by E. Braccio).

were eliminated by discarding all dubious values (damage greater than the settlement population) before risk calculation.

As for critical rain probability, Bacci (2016) considered only the meteorological stations that had continuous recording from 1981 to 2010. In the case of municipalities with no meteorological station, he used the registrations from the closest meteorological station upriver with the same hydrographical characteristics. Errors should have been eliminated at this point and the impact on results concerned only approximations we made assimilating critical rain of the upriver rainfall in the case of municipalities without rain stations or no significant precipitation (less than 20 mm) in the five days around the flood date.

It is useful to remember that, at present, there are no alternatives based on regularly collected data to provide a flood risk assessment at the municipal level more accurate than the one presented in this chapter. Daily river discharge could not achieve better results since only 13 hydrographical stations are operating (out of 20), and they are located on the river Niger and on its right bank tributaries only. Consequently, using this data 28 municipalities out of 44 (64%) would have no hydrographical measurements, thus flood data.

13.8 Conclusion

The flood risk can be assessed in each municipality of the Tillabéri region (Niger) starting from the daily rainfall (DMN), from the three-hourly data, and from the damage recorded by the EWS DP DB since 1998.

Almost half the municipalities have a yearly recurrent flooding hazard, meaning that large parts of the territory are continually threatened by flooding.

The EWS DP DB provided three relevant types of information.

Firstly, the identification of those settlements that were flooded more than once was provided, especially those hit two or more consecutive years, a catastrophic condition for the interested populations. Eleven per cent of the 765 flooded settlements were hit more than once and 19 settlements were hit for two or more consecutive years. Half of these cases affected the same municipal capitals.

Second, the contribution of an isolated damage event in determining the risk was provided thanks to the adoption of indicators built with the same methodology. This allowed us to consequently identify the priority sectors for DRR (people, dwellings, fields, and livestock).

Third, the identification of the municipalities that were at high risk of flooding was made possible. Despite the fact that there were only 7 municipalities at very high, high risk and 9 at and moderate risk of flooding, these were, in any case, administrative bodies that held 39% of the region's population. Ten out of the sixteen were municipalities on the edge of the River Niger and which were sometimes also crossed by the river's many tributaries such as Gorouol, Dargol, Sirba, Goroubi, Tapoa, Mékrou.

The cases of consecutive flooding exposure that we identified between 2010 and 2013 do not seem to be explained just by the occupation of exposed areas, but by the effects of climate change (higher intensity of flooding, out of season flooding). This would explain the lack of flooding adaptation measures in MDPs before 2012.

However, a lot remains to be done in order to adapt MDPs to climate change.

The awareness of the flooding risk on a municipal level is useful for:

1. Central structures: prime minister, CNEDD, ministries:
   - organising aid in advance to municipalities that are regularly flooded
   - supporting the preparation and adoption of municipal emergency plans
   - supporting the adaptation of MDPs to climate change for municipalities at very high, high and moderate risk
   - supporting the carrying out of adaptation measures provided by the MDPs through the constitution of a special fund (for example, to be created with the help of the development partners)
2. The municipalities, in order to practice evacuation in the most exposed settlements
3. The development partners, to support the adaptation of those settlements flooded more than once and those municipalities at very high, high and moderate risk of flooding

4. Professionals, in order to:
   - address their assistance during and after disaster
   - assist young people in case of disaster
   - teach their students the relationship between meteorology, flooding and development
   - incorporate the risk concept into the approach and activities of the NGOs

This chapter closes with some recommendations to the CNEDD and the EWS DP
- Adaptation should be monitored by settlement, especially in those frequently exposed to flooding
- The MDPs of the 16 municipalities most at risk of flooding in the Tillabéri region should be adapted to climate change
- Attention should be paid to the definition of risk, which is not synonym of exposure (see RN, DNPGCCA unk)
- The annual information sheet on flooding should include the cause of flooding (intense rain, the overflowing of watercourses that cross or border the flooded settlements, formation of water stagnation, etc.)
- Indicators should be weighed according to pastoralist, agro pastoralist or farmer areas
- The possibility of interrogating the EWS DB as web GIS should be considered

To mayors
- Depending on how high the municipality ranks regarding at risk of flooding, check those indicators that have the highest values and consequently identify the DRR measures and include them in the MPD, especially for settlements flooded more than once.

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