Risk factors of becoming a disaster victim. The flood of September 1st, 2009, in Ouagadougou (Burkina Faso)

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1. Introduction

The frequency and intensity of natural disasters are increasing in urban areas. Ongoing climate change will likely further increase these risks. The United Nations University Institute for Environment and Human Security (Bogardi, 2004) estimates that two billion people will be vulnerable to extreme weather events by 2050, unless preventive measures are stepped up. Some regions, such as the Sahel, are particularly sensitive, with increasing drought and rainfall fluctuations due to climate change (IPCC, 2007).

Urban areas can play a role in amplifying natural hazards: as more and more land is cleared to make room for urban development, erosion increases and runoff intensifies. Cities are particularly susceptible to floods, especially in Africa (Douglas et al., 2008). Paved ground, impermeable to water, limits drainage in some places and concentrates it in others, increasing runoff and peak flood flows. These increased risks are centered just where major social and economic issues are clustered. The situation in Africa is exacerbated by factors such as intense tropical weather patterns, where as much as several hundred millimeters of precipitation can fall in a 24-hour period. Costly drainage infrastructure, however necessary, is often not available due to severely limited financial resources. The severity of the situation has been illustrated time and time again, with the flooding that occurred in Niamey (Niger) in 1998 (Issaka and Badariotti, 2016), in Addis Ababa (Ethiopia) in 2006 (Douglas, Alam, 2008), in Abeokuta (Nigeria) in 2007 (Adelekan, 2011), in Ouagadougou (Burkina Faso) (PNUD and World Bank, 2010), or this year in Abidjan (Gouvernement de Côte d'Ivoire, 2018).

Yet, urbanization in Africa will be the most rapid in the world between 2020 and 2050, with a threefold increase of the urban African population during this period (United Nations, 2014). Nevertheless, the urban growth of African cities, especially in capital cities, is leading to the development of informal settlements that do not have access to basic services and sustainable settlements and housing (UN-Habitat, 2014). UN-Habitat estimates that one quarter of the world urban population lives in an informal settlement; one third of the developing urban population and almost two thirds of the Sub-Saharan urban population (UN-Habitat, 2014). Hence, in many urban areas in developing countries, the consequences of flooding are becoming increasingly severe, partly due to the spread of unregulated shantytowns.

In light of the expected growing natural hazards and the continued growth of urban populations, there is concern that the vulnerability of a significant portion of the urban African population will increase even further Therefore, there is a need for better understanding of the social dimension of climate change (ICSU, 2012), and especially for in-depth research on the main features of the populations most vulnerable to flood risks. According to the definition given by Turner et al. (2003), a comprehensive vulnerability analysis should considerer three main components: exposure, sensitivity and resilience to the

risk. The first refers to physical and geographical exposure. The second indicator is related to the environmental and human conditions associated with hazards (e.g. social capital, demographic and economic characteristics, institutions, economic structures, etc.). Finally, the third, resilience, consists of coping responses, impacts of hazards and adjustments post-disaster. The second indicator of vulnerability is specifically addressed in the present article, including the concept of social vulnerability.

Until recently, there were few studies that examine social factors related to natural disaster differentials (Pelling, 2007). Even though previous research has highlighted evidence of a relationship between exposure to natural disasters and poverty (Bern, 1993, Li et al., 2016), the complex processes underlying this association remain poorly studied. A recent review (Fatemi et al., 2017) identified 4 main individual or household factors that defined the social vulnerability to natural disaster : gender, demographic characteristics, socio-economic status and disability. By studying risk factors for mortality in the Bangladesh cyclone of 1991, Bern (1993) highlighted that the poor, women, migrants, the young and the elderly are more often vulnerable to natural disasters. More particularly, Cutter et al. (2003) showed that the households which have a woman for head of the household have a greater risk of social vulnerability, because of gender status in most countries in the world. The proportion of women in the household is equally positively associated with higher social vulnerability to disaster. Age groups, and specifically children of less than 5 and people 65 years and older, were highlighted as more vulnerable to disaster. The effect of education of the household head is more mixed (Fatemi, Ardalana, 2017). Few studies have taken into account all these factors in the same explicative model, all things being equal.

On the other hand, many studies are based on a qualitative approach (Douglas, Alam, 2008), which, although highly relevant for focusing on local perceptions, is less likely to draw specific conclusions regarding factors of vulnerability to disasters than a quantitative method (Adelekan and Asiyanbi, 2015).

Observation biases also occur. The social sciences usually construct their research questions and consider generally the issue of vulnerability to risk with a focus on the area delimited by the physical processes, as taken as conceived by the earth sciences (Metzger and D'Ercole, 2011). This implies that studies are rarely performed by analyzing social differentials between households having directly undergone damage, and those who have not - because the zone of study concerns only with the site of the disaster. And yet, this fine level of analysis is essential because factors of social vulnerability are thought of as context-dependent (Wisner et al., 2004). In addition, many quantitative studies have focused on the vulnerability characteristics of populations living in areas exposed to floods (Adelekan, 2011), or even studies on vulnerability to natural disasters are focused on resilience, i.e on strategies and resources to cope with the disaster, based on data coming generally from post--disaster field-surveys involving questioning some victims ex-post.

Finally, research is still very often focused on developed countries, and rarely concern developing countries (Fatemi, Ardalana, 2017). This issue is still insufficiently studied in African urban areas (Campion and Venzke, 2013) : few studies have examined what specific individual and household factors are linked to floods at a fine scale, e.g. the household level (Douglas, 2017), all things being equal. More specifically, and to our knowledge, very few

studies in sub-Saharan Africa have undertaken a soundly-based quantitative study of social vulnerability by comparing individual and household characteristics of the victims who have lost their houses and subsequently left their plot, with those of non-victims of the floods, given the complexity of finding those who have left their plot. The aim of the present article is precisely to attempt to make good this gap by contributing to a better understanding of the way socio-demographic and environmental living conditions influence vulnerability to a major flood impact (loss of housing) of social groups in west-African cities.

This study focuses on the city of Ouagadougou, the capital of Burkina Faso. On September 1st, 2009, the city experienced torrential rainfall, leading to water runoff and floods. Over 180,000 people were severely affected by this natural disaster and 35,000 of them completely lost their homes (PNUD and World Bank, 2010). We will first present the general background of Ouagadougou, by focusing on the rainfall regime and highlighting how exceptionally high the level of the precipitation was during September 1st, 2009. After describing the methodology and the originality of the study design, we will present the results, and discuss them. Finally, we will call for a more holistic approach to urban planning, with the aim of introducing an early warning system for flood risk in vulnerable areas such as informal settlements.

2. Background

2.1. Study area

Ouagadougou (latitude 12°21'N and longitude 01°31'E), the capital city of Burkina Faso, is part of the Sudano-Sahelian area. The town lies at an altitude of about 306 m above sea level and occupies an area of 518 km^2. Burkina Faso is one of the poorest countries in the world. With a per capita gross national income of US $1141, the country is ranked 181th out of 186 countries on the UNDP's Human Development Index (UNDP, 2013). With a population of 1.5 million (according to the 2006 census), the city of Ouagadougou is home to 46% of the country's urban population. The population growth of Ouagadougou is one of the most rapid worldwide. In almost 50 years, from 1960 to 2006, the date of the last population census, the population of Ouagadougou has increased 25-fold, from 59,126 to 1475,223 inhabitants (Boyer and Delaunay, 2009). The current population is estimated at 2800,000 inhabitants and the annual population growth rate at 5.9%, due both to natural growth and to rural–urban migration (INSD, 2009). According to median growth population projections, the city will reach almost 6 million residents by 2030 (UN/DESA, 2015).

With population growth, and the increasing prevalence of individual houses, the city has experienced rapid geographical expansion, growing in size from 14 square kilometers in 1960 to 520 square kilometers in 2009 (INSD, 2009). This mostly unplanned and uncontrolled spread of the urban population has reinforced its social and spatial segregation (Boyer and Delaunay 2009). Alongside the official sector, a customary sector enabled many of the less wealthy to find the means of accessing a plot. The unzoned neighborhoods - spontaneous and informal settlements where land has not been officially apportioned and deeded by the government - make up a third of the total area of the city, and approximately 35% of Ouagadougou's households live in those neighborhoods (Boyer and Delaunay 2009), where the people tend to be younger, poorer, less well-educated and more often migrants than

those living in formal settlements (Rossier et al., 2012). These peri-urban informal neighborhoods are traditional residential areas, characterized by single-family homes built from mainly local building materials. For example, the great majority of house walls in these areas are built of traditional adobe bricks, made with sun-dried mud blocks (Fournet et al., 2009). Informal areas also lack service from paved roads and drainage systems. Streets of any kind are largely absent, save for the sandy tracks created by the inhabitants. There are few trees, with very scarce and dry ground vegetation, few irrigated home gardens and a great deal of livestock grazing (Lindén, 2011). This precariousness leaves these residents extremely vulnerable to natural disasters.

2.2. Rainfall

Ouagadougou is part of the Sudano-Sahelian area and features a tropical savanna climate, with two very distinct seasons: the rainy season (which lasts approximately four months, from May/June to September), and the dry season, during which blows the Harmattan, a hot dry wind from the Sahara.

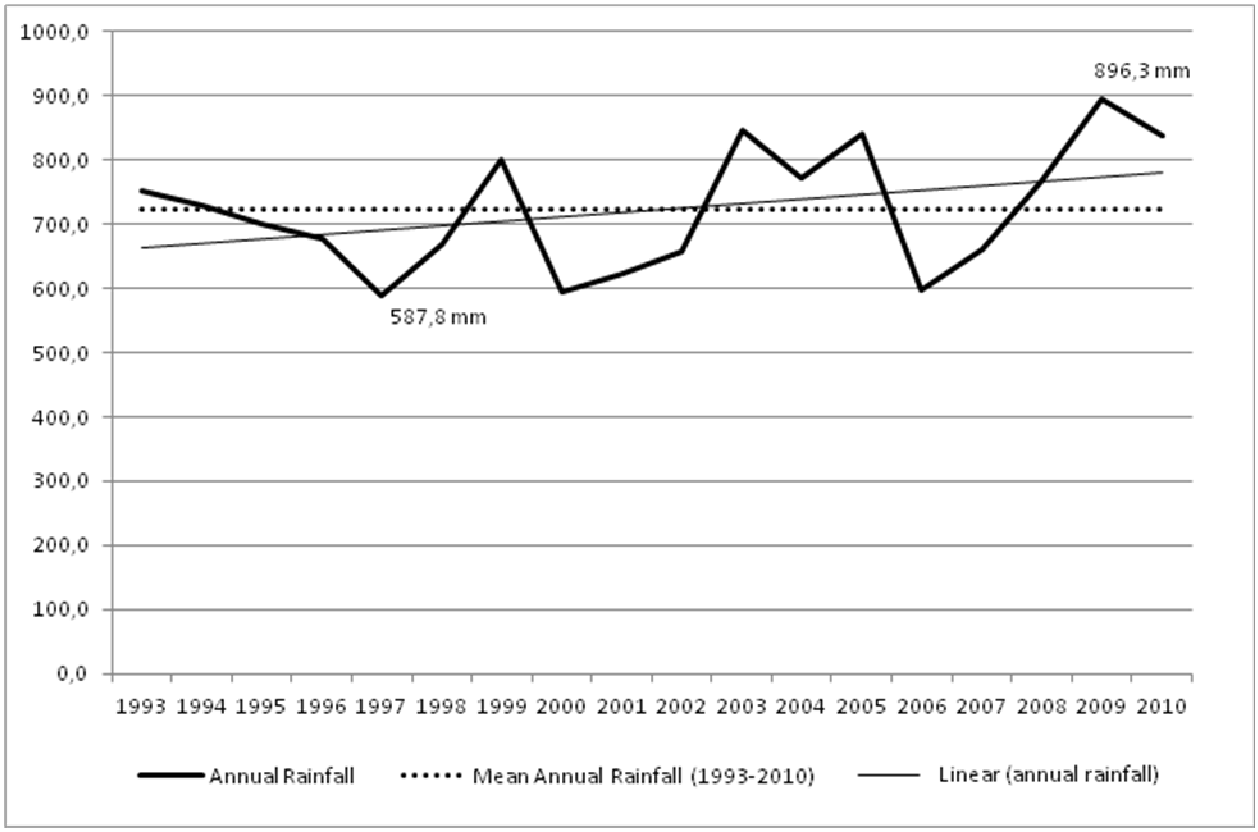

Figure 1. Annual rainfall in Ouagadougou (1993-2010)

The region is also experiencing a long-term downward trend in rainfall (Lebel et al., 2000), which has led to increasing cycles of drought and famine (Haile, 2005). For the city of Ouagadougou in particular, annual rainfall pattern for the period 1993-2010 shows a long-term downward trend in precipitation (Figure 1, thin line). In addition, Ouagadougou has experienced wide year-to-year variations in total annual precipitation, ranging from 588 mm in 1997 to 896 mm in 2009 (Figure 1, bold line). The mean annual rainfall for this period measured 722 mm (Figure 1, dashed line).

2.3. The magnitude of rainfall in September 1st, 2009

During the year 2009, 890 millimeters of water fell on the city of Ouagadougou, a record for the last twenty years. The distribution followed a relatively normal trend, with a rising level of precipitation during the period between June and September (Figure 2). The month of September, however, was particularly wet, with 34% of the total rainfall of the year 2009. The total rainfall during the month of September was largely due to a single event. In the early hours of September 1st, 2009, torrential rainfall began in Ouagadougou. The rain fell relentlessly for 12 hours, with 261 mm accumulating in that short time, representing 36% of the area's annual mean precipitation (1993-2010 annual mean), and 86% of the total monthly precipitation in September 2009.

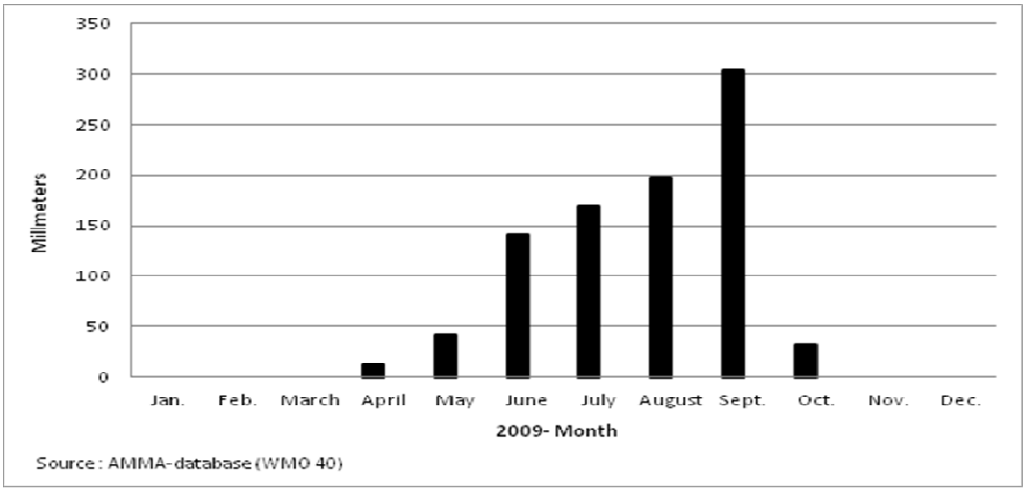

Figure 2. Monthly Rainfall in Ouagadougou in 2009

This extreme rainfall led to significant urban runoff and flooding that destroyed paths, felled trees and washed away poor quality houses. In terms of damage, it accounted for 41 deaths, 62 casualties, 180 386 people became homeless and 33 172 houses were destroyed; the damage has been estimated at almost $3 billion US (PNUD and World Bank, 2010). This toll is truly staggering for a developing country like Burkina Faso, especially by reference to the classification scheme proposed by Brooks et al. (2005), in which Burkina Faso is one of the most vulnerable countries in terms of its capacity to adapt to climate variability and, by extension, climate change.

3. Methods

3.1. Data collection

Data come from the Ouagadougou Health and Demographic Surveillance System (Ouaga HDSS). This is a research and intervention platform established in 2008 in five neighborhoods on the periphery of the city (Figure 3); two formal areas in which the land is deeded and government services are provided (Kilwin and Tanghin) and three informal settlements, essentially illegal settlements around the periphery of the city, without access to electricity, piped water and other public services (Nioko 2, Nonghin and Polesgo). In 2010, the population of the study area was estimated at 79,240 residents distributed among 17,975 households (Table 1).

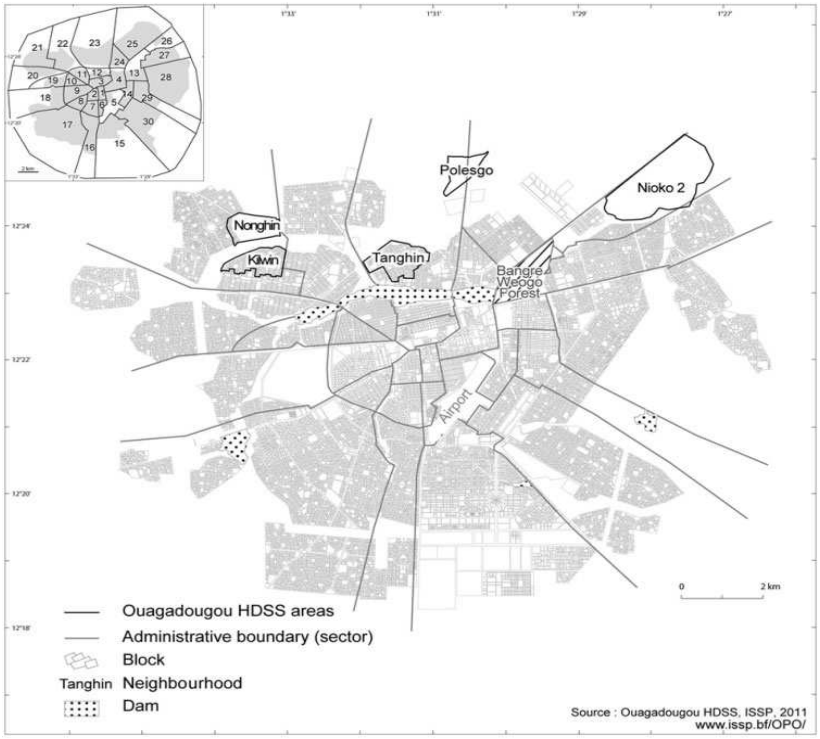

Figure 3. Location of settlements monitored by the Ouaga HDSS (Rossier et al, 2012)

Table 1. Number of households, usual residents and household size in each settlement monitored by the Ouaga HDSS, 2009

	Number of households	Number of usual residents	Household size
Formal	7,266	42,192	5.8
Kilwin	3,854	21,408	5.5
Tanghin	3;412	20,784	6.1
Informal	10,709	37,048	3.5
Nonghin	5,649	18,789	3.3
Polesgo	1,480	4,849	3.3
Nioko 2	3,580	13,410	3.7
TOTAL	17,975	79,240	4.4

3.2. Household characteristics

The Ouaga HDSS monitors an urban population in which poor individuals are overrepresented, but which is also socioeconomically diverse (Rossier et al. 2012). On the basis of household wealth, measured as a function of the durable goods present in the home (television, refrigerator, motorbike, car), households in the informal neighborhoods are more often poor (with 66% of homes classified as poor) than in formal neighborhoods (where only 27% are poor). The latter figure is comparable to the situation for the city as a whole. The informal neighborhoods of the Ouaga HDSS are nevertheless wealthier than the rural areas of Burkina Faso, where 73% of households are classified as poor.

Concerning tenure, 62% of households fully own their accommodation in the formal neighborhoods. In informal settlements, 81% of households own their accommodation

purchased through the traditional authorities, pending future zoning and formal housing developments during which plots will be allocated to local landowners. Associated with tenure and poverty, almost all households (99%) had a house made with mud in informal settlements, comparing with 74% of households living in a house constructed with cement bricks in the formal neighborhoods of the Ouaga HDSS.

3.3. An "unexpected" study design

During the first round of the Ouaga HDSS, in the first six months of 2009, a household survey collected data on household goods, economic activities, level of education, home ownership and housing characteristics. This survey was completed just before the disastrous flood. After the flood, in the course of a regular round, fieldworkers registered the households that had completely lost their houses and then disappeared from the database. This unique, "unexpected", design provides a rare and original dataset, especially in the context of West Africa, where national vital events data are poor and census data are not regularly updated. This gives us a unique opportunity to study the characteristics of the households which were victim of this natural disaster before the disaster, that is to say, households that completely lost their homes.

3.4. Data analysis

The aim is to estimate the effect of a set of independent variables, mainly examining head of household characteristics as related to the status of “disaster victim”.

Since our dependent variable is binary (a household was either declared a disaster victim or not), we used a logistic regression. The model can be expressed as:

$$ln(q_i/1-q_i)=\beta_0 + \beta_i x_i$$

where q is the probability of being declared as a disaster victim for the ith household, β_0 is the baseline constant, β_i is a series of unknown coefficients and x_i is an array of independent variables. The estimated coefficients (β_i), when exponentiated, are interpreted as the odds of being a disaster victim ($q_i/1-q_i$), with certain characteristics relative to the odds of being a disaster victim in a reference (or baseline) group of households: that is, relative odds or odds ratios (OR).

To better understand the effects of the household factors net of other key covariates, variables were introduced separately into the models, allowing for a comparison of coefficients across the different equations. The status of disaster victim is then modeled step by step according to certain characteristics of the head of household or of the household itself. A modeling process in four stages was performed. Model 1 tests these to see if their effect is as expected. Consequently, this model included only socio-demographic and economic characteristics of the head of household (sex, age, education and wealth index). Model 2 incorporated housing characteristics (sanitation availability, source of lighting, age of the house and occupation status of the head of household). Model 3 adds the migrant status of the head of household (place of birth and duration of residence in Ouagadougou). Finally, Model 4 tested all the variables mentioned earlier, including the composition of the household (marital status of the head of household, the number of usual members in the household and the sex ratio in the household).

Before estimating these models, we analyzed some descriptive results to sketch the urban heterogeneity in terms of socio-economic and environmental conditions. Geographical mapping analysis was performed by using MapInfo Version 9.0 for Windows, and statistical models were performed using Stata Version 11.0.

4. Results

4.1. Descriptive results

Though there was only one neighborhood that completely escaped large-scale damage, in the areas monitored by the Ouaga HDSS, the large majority of disaster victims were concentrated in a single zone, the informal neighborhood of Nioko 2. This concentration begged the question of what distinguishing characteristics of Nioko 2 led to such destruction, while other neighborhoods (even informal ones) were relatively spared.

At first glance, Nioko 2 presents the typical characteristics of informal settlements: unsanitary living conditions, very poor quality housing, mainly single-family homes, no paved roads and no drains; sandy tracks, few trees and very sparse and dry ground vegetation, etc. From a demographic and socio-economic perspective, the vast majority of heads of household declare themselves as owner of their plot of land, even if this ownership is not legal and remains traditional. They are generally younger, living in a nuclear family, and tend to be poorer than those in formal settlements.

The biggest difference between Nioko 2 and the other informal settlements measured by the Ouaga HDSS concerns certain notable physical characteristics. In particular, this area is completely surrounded by a water system (Figure 4). Of the 3,580 households followed by the Ouaga HDSS, 311 (8.7%) of them are classified as disaster victims, completely losing their homes to the flood. All of these households were situated at the neighborhood's lowest-lying point, at the border of a gully, just in front of a canal (Figure 4).

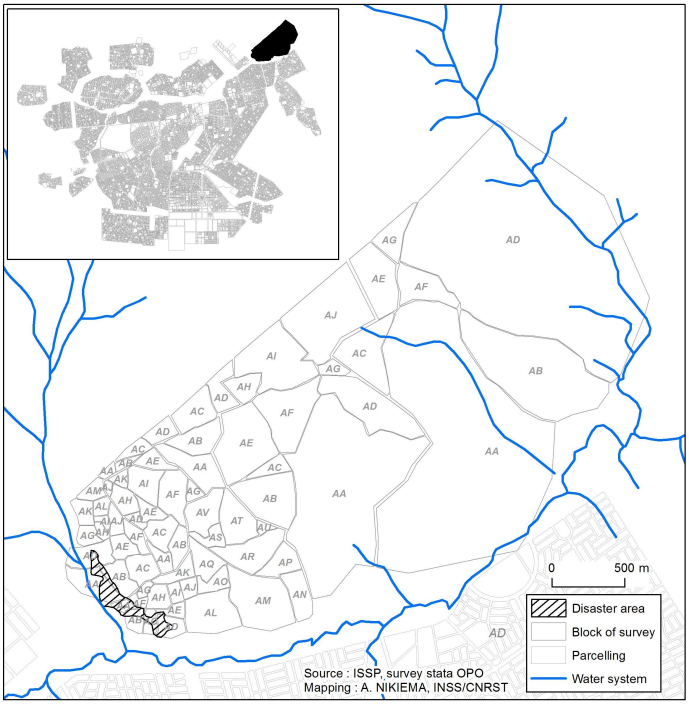

Figure 4. Location of the disaster areas in Nioko 2 monitored by the Ouaga HDSS

Figure 5a. Map dated 31th March 2009

Figure 5b. Map dated 5th December 2012

Figure 5. Maps from Google Earth: location of the disaster areas (red line) monitored by the Ouaga HDSS

A glance at the maps extracted from Google Earth before (31st March 2009) and after the disaster (5th December 2012) is illustrative of the extent of the disaster in this area. The red lines encircle the disaster area monitored by the Ouaga HDSS. After the storm, no houses remained in this zone or around the water system in general (Figure 5). Hence, a key predictive variable is the proximity to the gully, as the correlation between the latter variable and the status of disaster victim in this study is equal to one.

Given the precise location of exposure, it is interesting to explore, all things being equal, the other characteristics of the heads of the households that had established their homes in such a risky zone.

4.2. Multivariate results

Table 2 presents the results of the multivariate analysis, including characteristics of the head of household. Our results are generally consistent with the literature (scientific and grey) on individual and household variables associated with vulnerability to extreme events, in the sense that it is the result of the combination of several socioeconomic factors of social inequalities (e.g. Campion and Venzke, 2013, Cannon, 2010, Cutter, Boruff, 2003, Rufat et al., 2016). The effect of the age of the head of household is particularly noteworthy: younger heads of household had lower risk of becoming a disaster victim than older heads of household. This was even more marked when comparing heads of household between 35-49 years old with the reference category (under 35 years old). Both education level and wealth were significantly associated with the status of disaster victim, as expected. Households where the head had no formal education, and poorer households, had higher risk of completely losing their home during the storm. A recent review highlights how (Rufat, Tate,

2016) this set of socio-demographic variables are key factors in explaining social vulnerability to floods.

There was one result, however, that went against the expectations of the literature. Households where the head was a woman had a lower risk of becoming a disaster victim, nearly 50% less than households where the head was a man. Hence, before discussing this unexpected but intriguing result of the gender effect observed here, we have to make sure that this result is robust and persistent when other household characteristics are included in the model.

The introduction of some more refined socioeconomic factors had noticeable effects on variables included in Model 1, especially on the variable used to measure levels of wealth/poverty. The effect of this proxy wealth index, based on the possession of functional durable goods, was no longer significant when the availability of sanitation and the source of lighting were included in the model. In contrast, the odds ratios associated with those variables were very high and significant, highlighting the extreme economic vulnerability of the households that were victims of the disaster (no sanitation and cheap source of lighting).

A look at how long a household had been present on the plot also gives interesting findings. Households in place there for three to nine years were more at risk than newcomers (who had been there less than three years), or households installed for ten years or more. Thus, it seems that the oldest households (in terms of duration of residence in the neighborhood) settled in the least risky areas, the most suitable in terms of topography, because they were the first to arrive. For their part, the most recently arrived households were probably better informed about the risks of living in low-lying areas, at the edge of a gully. Better informed of the risks (catastrophic events more widely broadcast, etc.), these newcomers have settled less in those areas at risk, mostly already occupied by households that arrived in the preceding years.

Though the effect of the occupation status is not significant, the direction of the odds ratios follows the expected gradient. Those who owned the home in which they live seemed to be at greater risk of losing the house during the storm than those who rent. This result is not surprising, given the literature on urban residential integration on the outskirts of Bamako (Marcoux et al., 1995, Morin et al., 1996), the capital of Mali (a neighboring country), where households who rent were better equipped than those who own their homes. One possible explanation for this is that people are willing to make some trade-offs (such as foregoing urban services and infrastructure) in exchange for owning their own homes. In Ouagadougou, too, home ownership is a top priority for many, ranked above housing quality or access to water (Dos Santos and Le Grand, 2013). Furthermore, since those living in informal areas often do not legally own their plots of land (which have yet to be officially allocated by the municipality), they are reluctant to invest in high quality permanent structures. Rather, they prefer to construct provisional housing on the plots to “save their place,” so that when the land is formally allotted, they will have staked the first claim. Another hypothesis would be that tenants are more concerned about the location of their rented housing, while some households agree to become homeowners on more risky plots (e.g. at the border of a gully).

As expected, the place of birth seems to play a role in the risk of becoming a disaster victim. Those of rural origin were the most at risk, which was expected in the light of the literature on the process of the urban in-migration carried out in several major cities in West Africa (Campion and Venzke, 2013), and on residential trajectories (Antoine et al., 1998). Length of time lived in Ouagadougou impacts results in the same direction as length of time lived on that given plot of land. The intermediate duration (10-29 years) in Ouagadougou was significantly associated with a much greater risk than a shorter duration in Ouagadougou (less than 10 years) or a longer duration (30 years and over). A similar explanation can be found as for the duration of residence on the plot, but a deeper understanding of the complex processes underlying this association still needs to be sought. We can note that the effect of the demographic and socioeconomic characteristics of the head of household was unchanged by the introduction of migration status (stable odds ratios between Models 2 and 3).

Finally, three variables were intended to serve as proxies for the composition of the household. First, marital status played a role with regard to the phenomenon under study, as married heads of household were much more likely to be disaster victims than those who were never married. The number of usual household members, however, did not seem to be associated with the risk of losing the house during the storm. The sex ratio in the household, though, did follow a meaningful gradient, even if the odds ratios were not significant. The more men there were in the household, the less the household was at risk. We have no hypothesis for possible explanations for this result, which remains, moreover, not statistically significant. We can only note that the introduction of this variable strengthened the effect of the sex of the head of household in Model 4 (as compared to Model 3). Many studies have highlighted the importance of the gender variable as an important factor of social vulnerability to floods (Mukuna, 2015), but this is especially important when it is interacted with other social factors, such as family structure (Ajibade et al., 2013).

Table 2. Factors influencing the "disaster victim" status - Ouagadougou HDSS (preliminary results)

Variables of the head of household	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Sex (male)				
Female	0.56**	0.58*	0.61+	0.47 *
Age (< 35 years)				
35-49 years	0.66**	0.77+	0.74*	0.71*
50 years and over	0.73+	1.09	1.12	1.09
Education (none)				
Primary	0.46***	0.45***	0.48***	0.50***
Secondary and higher	0.39***	0.37***	0.39***	0.40***
Wealth index (low)				
Medium and high	0.68**	0.88	0.86	0.84
Sanitation (no facility/bush/field)				
Latrine		0.26***	0.23***	0.23***
Source of lighting (lamp with kerosene/modern)				
Flashlight		3.35***	3.44***	3.51***
Other (candle, none, etc.)		1.51	1.56	1.58+
Duration of residence on the plot (less than 3				
3-9 years		1.73***	1.69***	1.77***
10 years and over		0.15***	0.24***	0.26***
Occupation status (owner)				
Tenant		0.68	0.66	0.60
Hosted		1.28	1.25	1.26
Place of birth (rural area in Burkina Faso)				
Ouagadougou			0.42***	0.46***
Other towns of Burkina Faso			0.86	0.85
Abroad			0.14*	0.13*
Duration of residence in Ouagadougou (less than				
10-29 years			1.72***	1.68***
30 years and over			1.00	0.97
Marital Status (never married)				
Married				1.73*
Divorced, separated or widowed				1.44
Number of usual members (1)				
2-3				0.98
4-7				0.80
8 and over				0.49 +
Sex ratio in the household (1)				
Household without men				1.72
Sex ratio < 1				1.27
Sex ratio > 1				0.88
Household without women				0.86

Reference category in parenthesis.

Significant levels : *** p<1% ; ** p<5% ; * p<10% ; + p<15%

Discussion

Global environmental change has led to a burgeoning literature on climate change vulnerability and adaptation. One part of this literature focuses on developing higher-resolution climate models to better characterize uncertainty in the regional climate projections offered to decision-makers – the "top-down" methods. The other part deals with past and present climate variability for reducing vulnerability, in a "bottom-up" approach (Wilby and Dessai, 2010). Climate impact on populations will largely depend upon a large set of socio-economic determinants pertaining to individual and household levels (Rufat, Tate, 2016), as well as local and national levels (Brooks, Adgera, 2005), and the role of institutions as adaptive capacity drivers (Berman et al., 2012). In this sense, and as social scientists, we wanted to contribute to the second part of this literature, as we believe, along with Washington and colleagues (Washington et al., 2006), that coping with present climate variability is enough of a challenge, particularly in growing and partly uncontrolled urban areas.

This paper helps to document how natural hazards can amplify urban inequities (Reckien et al., 2017), by highlighting the low resilience of some households compared to others (in another context, see also (Linnekampa et al., 2011). In Ouagadougou, almost 180,000 people have seen their housing totally destroyed by the waters during this extreme event, or nearly 10% of the total population of the city. The results presented here confirm that they were among the poorest. Generally, living standards indexes based on habitat characteristics (nature of the roof, walls, soil) and durable consumer goods are barely adequate to differentiate the heterogeneity of poverty situations (Kobiané, 1998). Certain socio-economic factors are more discriminating markers of vulnerability than others. Results show how the variables related to the environmental conditions of life (sanitation, source of lighting) are much more discriminating than those of the wealth index (habitat and goods). In this case-study, the evidence still confirms that it is especially the most precarious of them who have been affected, those who do not have the minimum necessary to live for a decent life, that is to say, a private place to meet their natural needs (no latrines), and a rudimentary lighting mode (candle or flashlight). In informal areas in OPO, only 10% of households do not have sanitation. These households are among the most vulnerable in terms of health, for example, but also, as we have just seen, of vulnerability to flood risk. These are the ones that already had the lowest resilience to withstand such a shock. Disasters, even if less severe, and more generally accidental events (illness, loss of employment, etc.) are accelerators of precariousness, because they erode the fragile resilience of some households.

In terms of response capabilities, and in the face of this extreme event, which had not been anticipated by any early warning system, society as a whole was relatively resilient. Thanks to the support of the Government and its partners, essentially the European Commission, two shelters, named Yagma and Basséko, were set up in the far outskirts of Ouagadougou to welcome flood victims from 2009 in Ouagadougou. In particular, in the Yagma welcome network, located about 20 km north-west of Ouagadougou, more than 24,000 households are sharing this site of about 900 hectares. In addition to a plot, households received materials to build a house, namely bags of cement and 20 sheets of corrugated iron. The government has put in place certain infrastructure such as schools. Six years after the first

installations, a health center was constructed. However, locals believe that this is insufficient, in particular in terms of access to water and road infrastructure. While many households had to abandon their professional activities, mainly in the informal sector, having lost their raw materials during the flood, the remoteness and isolation of this site did not favor the resumption of an activity. In addition, a number of households have left the site, preferring to sell the plot and return to the center of the city in order to find a job.

Consequently, and for some years, the inhabitants have been returning to the sites which have been devastated. This is particularly true for the area studied in this article, the neighborhood of Nioko 2 (Figure 6). Field surveys show that households are gradually reoccupying their plots. It is particularly remarkable to the north of the disaster zone under study in this article, delimited in red. The same plots of land, of which they are not officially owners, have nevertheless been bought from the chief of the neighborhood. Knowing the risks involved, having already suffered in 2009, the inhabitants make the reasoned choice of a return, and explain this with a common expression: 'it is always better to sleep on your own mat than that of someone else". Thus, as Issaka and Badariotti (2016) point out in the case of Niamey, having a plot in a high-risk area can also be seen as a survival strategy, in cases of increased vulnerability. In a context where access to land to build a house, however precarious, is perceived as the priority of priorities, settling on this type of plot can be perceived as a guarantee of land tenure. This risk exposure ensures that there is no risk of "expropriation" by the municipal authorities, because the plot has no market value. This perceived risk does not therefore outweigh a day-to-day empiricism which, in a geographical context where it only rains a few weeks a year, dictates that the balance of costs and benefits tends to make it a rational preference to accept a share of risk .

Figure 6. Map from Google Earth: location of the disaster areas (red line) monitored by the Ouaga HDSS (dated 12th October 2017)

Conclusion

The aim of this paper was to examine the socio-demographic and economic risk factors of "disaster victim" status based on the case study of the storm of the September 1st 2009 in Ouagadougou. The availability of data from a Demographic Surveillance System – the characteristics of the population as well as that of their dwellings before the flood of September 1st 2009 - offered a unique opportunity to address the impact of such an event among the different social groups. Exploring these original data, we aimed to document risks factors of this extreme event in order to reduce vulnerability in preparation for future disaster.

The neighborhood of Nioko 2 is one of the vulnerable areas that the Ouaga HDSS monitors. Preliminary results suggested that the 9% of the households who fell victims to the natural disaster were also the most vulnerable from a socioeconomic standpoint as well. These results suggest that natural disaster exposure is influenced by a range of socioeconomic and demographic factors. Results reinforce the idea that the main cause of disaster is not hazards, but even more the vulnerability of the population given the role of variables related to extreme poverty (no sanitation, no sustainable light) as determinant factors.

This study provides evidence on the necessity to integrate socioeconomic and demographic factors in effective mitigation and adaptation strategies. Measures must be taken to enhance the quality of life of the poor, through improvements in housing conditions and the development of strong disaster preparedness campaigns. We believe, along with Terri Cannon, that "hazards are natural, but that in general disasters are not, and should not be seen as the inevitable outcome of a hazard's impact" (Cannon, 1994, p. 13). The results presented here show how environmental living conditions allow a reinterpretation of markers of social and economic vulnerability to the risks of natural disasters. These type of variable are better able to capture extreme vulnerability rather than more traditional economic indicators, such as a poverty index using the possession of durable goods. Thus, the possession of toilets and the type of lighting better capture the risk of becoming a disaster victim than the index of standard of living. This result thus questions the importance of the temporalities of vulnerability: at certain moments in life, vulnerability can be accentuated, even if certain material goods are acquired. This result thus completes the analytical framework of Turner (Turner, Kaspersonb, 2003) in integrating environmental living conditions, complementing data from other social sciences and from earth sciences, to help in developing effective policies.

The manifestations of climate change and environmental change, coupled with the increase in food, water and energy insecurity that the large cities of sub-Saharan Africa are already facing, are beginning to provide a good understanding of the extreme urgency of rethinking urban management priorities in order to prepare for the growth of the cities of the 21st century. These floods have also revealed dysfunctions in governance, urban planning, infrastructure maintenance and land management, as well as the lack of an early warning system. There is a need for future research that will combine the delineation of flood-prone areas (De Risi et al., 2014) and urban dynamics in certain hot-spots in Sub-Saharan Africa, in particular by making greater use of the opportunities offered by spatial planning (Biesbroek et al., 2009). In particular, recent studies have attempted to assess the limit state of safety where the life of inhabitants of informal settlements is at risk of flooding (De Risi et al., 2013). In

Sub-Saharan Africa, early warning systems should be seen as essential in urban settings, not only for drought, but also for floods. There is a real opportunity to think of new, more holistic paradigms, including all scientific areas (pluri-disciplinarity) and all stakeholders, that will be better able to meet the particular needs of the vulnerable urban populations of Africa today, and especially on the basis of a longer-term vision.

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