FLOOD IMPACTS ON HOUSEHOLD'S WELFARE AND MAXIMAL ACCEPTABLE FLOOD RISK IN COTONOU

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Abstract

The number of people exposed year after year to natural disasters (lack of water, excess of water, strong winds, and earthquakes) is very high. Among natural hazards, those from extreme weather, especially floods, are more frequent and affect the greatest number of individuals. Generally in Benin, and particularly in the city of Cotonou, flood constitutes a serious issue every year. This study aims to analyze the impact of floods on the population's welfare and the maximal acceptable risk by population settling in flood-prone areas in order to know more about the real situation. A survey has been implemented on 150 households that are in the areas prone to flood risk randomly drawn within the research field for that. It reveals that households are really affected by the negative consequences of floods. Moreover, it shows that, households living in flood-prone zones are exposed to risk level that is greater than the maximal risk they accept. An econometric analysis of the maximal acceptable risk is carried out in order to find out its main explanatory factors. Among other, the results show that the households whose heads are men are willing to bear more risk that those that are headed by women.

Key words: *Natural disasters, climate change, impact, flood risk, maximal acceptable risk, Cotonou*

Introduction

The number of people exposed year after year to natural disasters (lack of water, excess of water, strong winds, earthquakes, etc.) is very high (Anctill, 2008). Among natural hazards, those from extreme weather, especially floods, are more frequent and affect the greatest number of individuals (Veyret and Garry, 1996). According to statistics from 92 countries (United Nations, 2007 in Anctill, 2008), a half of billion people would be affected by flood per year, the three out of five of them living in India (110 million), in China (100 million), in Indonesia (50 million) and in Bangladesh (40 million). During the period of twenty years between 1980 and 2000, three out of four people have been exposed to a natural disaster (United Nations, 2004 in Anctill, 2008). Natural disasters currently are due partly to climate change. IPCC (2007) argued that, a global assessment of data since 1970 has shown it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems.

According to Grelot (2004), flooding of an area refers to a non-instantaneous phenomenon which has a beginning and an end. It can be considered as an uninterrupted succession of states of submergence of a territory. Generally in Benin, and particularly in the city of Cotonou, flood constitutes a serious issue every year. Heavy rainfalls have taken place from September 13, 2010 in Benin, causing widespread flooding. Torrential rains and floods have created high flooding which affected 55 municipalities out of 77 in the country. The floods have caused a number of homeless people estimated at around 100,000 and have created serious infrastructure damages. These homeless people have lost all or part of their personal belongings and are seriously threatened in their daily lives. 43 people have lost their lives according to the United Nations Office for the Coordination of Humanitarian Affairs (Bureau des Nations Unies pour la Coordination des Affaires Humanitaires-OCHA) and epidemics threaten are developing, particularly cholera which caused 7 deaths in Benin over the past four months [European Development Fund (EDF), 2010].

The concept of maximal acceptable risk has been developed within the framework of the method "Inondabilité" by CEMAGREF (La Recherche pour l'Ingénierie de l'Agriculture et de l'Environnement). According to the method "Inondabilité", one has to be careful regarding the semantic interpretation of the term maximal acceptable risk. Indeed, the adjective maximal is not related to the physical parameters of the water height, speed or duration of flooding, but to the frequency of occurrence of this

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phenomenon, given physical parameters. Before deciding to live or after starting living in the areas which are prone to floods, the individuals may have information about the real situation of these areas. Therefore, they may accept to cope with a certain level of flood risk which is called maximal acceptable risk. According to UNISDR (http://www.unisdr.org/we/inform/terminology.htm, accessed January 15, 2013), acceptable risk refers to the level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions.

Risk is function of hazard and vulnerability. Fekete (2010) defined hazard in the case of river floods, as a natural event that is perceived as a threat and not as a resource by humans. Vulnerability to climate change refers to: "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007).

In Cotonou, a part of the population settled in the floodplain of Lake Nokoué and of the lagoon of Cotonou, and also in the wetlands. Indeed, Cotonou suffers from lack of genuine policy on land management. This situation is detrimental to the city (Mairie de Cotonou, 2008). Thus, the population is exposed annually to flooding. In fact, Cotonou due to its geographical position and its relief is at risk of flooding. Within this context to avoid to a part of the population of Cotonou to continue living in perilous situations and in extension of the reflections regarding environmental policies in developing countries, it is necessary to analyze the impact of floods on the population welfare and the maximal acceptable risk by populations settling in flood-prone areas in order to know more about the real situation. Also, this study aims to model the maximal acceptable risk.

Study Area

Cotonou is chosen for this study because it is the main city Benin. It is the economic capital of the country and is affected every year by flooding. Cotonou was erected as department since the last administrative division (department of Littoral). It is the smallest of the twelve departments of Benin in terms of land area. Its boundaries are: in West by the commune of Abomey-Calavi, in East by the commune of Seme-Kpodji, in South by Atlantic Ocean and in North by Lake Nokoué. It is located at the intersection of 6°20 North and 2°20 East, it and covers a land area of 79 km^2. It is composed by 13 districts and 140 neighborhoods. Cotonou is bisected by the channel called "Lagoon of Cotonou" which constitutes the direct communication between the Lake Nokoué and the sea, and the channel was built in 1894 by the French. Its terrain is relatively homogeneous and its altitude varies between 0.4 m and 6.5 m above sea level, and there are wetlands within its territory. Cotonou obeys to the same climate features like the whole southern Benin. There are two rainy seasons and two dry seasons:

- A great rainy season from mid-March to mid-July;
- A dry season from mid-July to mid-September;
- A short rainy season from mid-September to mid-November;
- A great dry season from mid-November to mid-March.

The rainfall occurs mainly between March and July with a peak in June (300 mm to 500 mm). It should be noted that due to climate change the rainfall patterns are shifting and they are focussing on the period from late May to early July.

Regarding soils, Cotonou stretches of sandy soils which are mostly acidic. The vegetation cover is difficult to identify due to the dense occupation of urban space which has eliminated the species characteristic of sandy-clay soils and hydromorphic replaced by anthropogenic species. A coastal sandy soil, with a width between 2 km and 5 km cut by lagoons and marshes, extends along the coast. The average monthly temperatures range between 27 and 31 degrees centigrade. The differences between the hottest month and the coolest one do not exceed 3.2 degrees. The months from February to April are the hottest months and those from July to September are the coolest ones. Cotonou has no river, but it adjoins Lake Nokoué (85 km^2) and some swamps constitute the department water tanks.

In 2002, the population of the department of Littoral amounted to 665,100 inhabitants according to the third General Census, and one can find 94.5 males per 100 females. It was predicted to be around 950,171 inhabitants in 2013 [Institut National de la Statistique et de l'Analyse Economique (INSAE), 2008]. Its demographic weight is about 9.82% of the Benin population with a density of 8,419 inhabitants per km^2. Regarding social and community infrastructures, Cotonou remains the department that has more infrastructures due to its status of economic capital of Benin.

In Cotonou, there is no real housing policy; public authorities allow people to settle in any area, which exacerbates the problem of flooding. Tenants represent 49%, the untitled owners 15%, titled owners 4% and there are 15% of family houses. The types of houses found in Cotonou are: grouped houses (79%), detached houses (10%), villas (4%), buildings (4%), isolated boxes (2%), and other (1%). Regarding the roofs of houses, the sheet metal is the material mostly used (87%), and then comes the flagstone (8%), tile (3%) and straw (1%). The floor of the houses is mostly in cement (90%), and then follows the tile (6%) and soil (3%). More than eight out of 10 houses were built of brick wall in Cotonou.

Figure 1 Map of Cotonou

Source: Institut Géographique National (IGN)

Methodology

Theoretical modelling

The theory of consumer (utility maximization) is used to model the maximal acceptable risk. The household programme is the following:

$$\begin{cases} Max_{C_t} \sum_{t=0}^{n} \frac{E(U_t[C_t(X,h)])}{(1+r)^t} \\ S/t \\ A_0 + \sum_{t=0}^{n} \frac{Y_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t(X,h)}{(1+r)^t} \geq 0 \end{cases} \quad (1)$$

where, A_0 is the household initial wealth, h, the house good, X, the vector of the other goods, $C_t(X,h)$, the household consumption level at time t, Y_t is the household income at time t, r, the discount rate, and n the number of years that is supposed to be finite. $E(U_t[C_t(X,h)])$ is the expected utility since the household is acting in risky environment (flood risk). Then, the Lagrangian for the household problem is:

$$L(C_t,\lambda) = \sum_{t=0}^{n} \frac{E(U_t[C_t(X,h)])}{(1+r)^t} + \lambda\left(A_0 + \sum_{t=0}^{n} \frac{Y_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t(X,h)}{(1+r)^t}\right) \quad (2)$$

By resorting to the Kuhn and Tucker conditions, one will get the consumption level for each period. Then, substituting the consumption levels into the objective function yields the maximum household's utility level. One has to mention that the household has to choose between two types of houses namely, the one in flood prone areas and the one in another zone that is not prone to flooding based on the intrinsic factors of each of them such as prices, proximity to the work place. Let us suppose that h_f is the house in flood prone areas, h_o is the other house.

With h_f, the household will get $\sum_{t=0}^{n} \frac{E(U_t[C_t(X,h_f)])}{(1+r)^t}$ and with h_o, $\sum_{t=0}^{n} \frac{E(U_t[C_t(X,h_o)])}{(1+r)^t}$

The household will choose h_f if and only if:

$$\sum_{t=0}^{n} \frac{E(U_t[C_t(X,h_f)])}{(1+r)^t} > \sum_{t=0}^{n} \frac{E(U_t[C_t(X,h_o)])}{(1+r)^t} \quad (3)$$

If $\sum_{t=0}^{n} \frac{E(U_t[C_t(X,h_f)])}{(1+r)^t} = \sum_{t=0}^{n} \frac{E(U_t[C_t(X,h_o)])}{(1+r)^t}$ the household will be indifferent between these two houses. In the latter case, the choice will depend also on the household risk aversion.

When the household opts for h_f, he is aware that he will bear flood risk. The level of $\sum_{t=0}^{n} \frac{E(U_t[C_t(X,h_f)])}{(1+r)^t}$ depends on the occurrence of floods every year. The household assigns to h_f a certain level of risk he is willing to bear, that means his maximal acceptable risk, which is linked to his characteristics. Thus:

$$RISQMAXI = f(household\ characteristics) \quad (4)$$

Empirical model

Equation (2) helps to draw the empirical model of the maximal acceptable risk. Therefore:

$$RISQMAXI = f\begin{pmatrix} demographic\ variables, residential\ variables, \\ and\ variables\ of\ psychological\ control \end{pmatrix}$$

(3)

Twelve independent variables are taken into account in the modeling of maximum acceptable risk. These are:

- Demographic variable: gender of household head (SEXE), household size (HHSIZE), age of household head (AGE) and its square (AGE2);
- Residential variables: household status relative to its housing (PRO), the factors conditioning the installation of household in the area (Near shops, the workplace, schools and transport (PC), and financial factors: attractive prices of land or of housing (FF)), be resident of the floodplain of Lake Nokoué or the lagoon of Cotonou (INON), the duration of the household in the area (TEM);
- Variables of psychological control: having information on the fact that the area is prone to floods before installing (INF), the opinion of households on a statement (a person has the right to live wherever he wants, whatever the type of risk incurred (PDVR)), perception about the fact to backfill the wetlands with any kind of waste (INS).

Since the maximal acceptable risk contains four modalities, it is estimated by a multinomial probability model. Ordered multinomial probability model is chosen, this, because of the orderliness of the maximum acceptable risk level. Therefore, one has to choose between the ordered multinomial Probit and Logit models, and it is the first one that is chosen (ordered multinomial Probit).

The impact analysis is done through descriptive statistics.

Data Collection

The data used for the study were obtained from the survey conducted by the author during March 18-25, 2011. A questionnaire was developed within this framework. The survey covered a sample of one hundred and fifty (150) households living in flood-prone areas of Cotonou. Normally the sample size should be at least more than 400 households, but due to the financial means it has been limited at 150 households. The administration of the questionnaire was carried out by direct interview. The study also uses primary and secondary data from INSAE. The study area was divided into three parts:

- Z_1: which is composed by four districts that are located in the east of the lagoon of Cotonou (first to fourth district);
- Z_2: which combined sixth, seventh, eighth, ninth and tenth districts;
- Z_3: that is composed by the fifth, eleventh, twelfth and thirteenth districts.

This grouping was done taking into account the geographical proximity of districts. Four neighborhoods which are recognized affected by flooding were randomly selected in each zone. Thus twelve neighborhoods were selected. The number of households surveyed in each zone is presented in the table 1.

Table 1 Households surveyed per zone

Zones	Number of Households	Demographic weight	Number of households to be surveyed	Survey rate
Z$_1$	47.216	30,59	46	1/1.000
Z$_2$	58.531	37,92	57	1/1.000
Z$_3$	48.599	31,49	47	1/1.000
Total	154.346	100	150	1/1.000

Source: Recensement Général de la Population et de l'Habitat 3 (RGPH3), INSAE, 2004

From the table 4, one can notice that 46 households are surveyed in zone 1, 57 in the second zone, and 47 in the third one.

Table 2 Households surveyed per neighborhood

Zones	Neigghborhoods	Number of households	Demographic weights	Number of households to be surveyed
Z$_1$	Dédokpo	1.114	17,95	8
	Adogléta	1.302	20,98	10
	Minontchou	1.109	17,87	8
	Avotrou	2.682	43,20	20
	Sous total 1	6.207	100	46
Z$_2$	Fifadji	7.096	62,28	35
	Vèdoko	952	8,36	5
	Ladji	1.220	10,71	6
	Yénawa	2.125	18,65	11
	Sous total 2	11.393	100	57
Z$_3$	Fidjrossè-Kpota	6.186	37,09	17
	Agla	8.489	50,90	24
	Houéyiho II	1.143	6,85	3
	Cadjèhoun	860	5,16	3
	Sous total 3	16.678	100	47

Source: Data from RGPH3, INSAE, 2004

This distribution was made taking into account the demographic weight of each zone. After that, the distribution of households to be surveyed per neighborhood was done. This distribution is in Table 2. For the remaining aspects of the survey design, please refer to Lokonon (2012).

Results and Discussion

The survey covered 150 households in the city of Cotonou having their houses in the flood-prone zones. Only people living in flood-prone areas were surveyed because they are the ones who directly use to experience the negative consequences of flooding. Due to the emergence of flood risk management the response rate amounts to 100 %. The households were really happy to know that this kind of study is carried out. 109 owners and heirs were surveyed (72%) against 41 tenants and other (27.3%). Insofar as floodplains are unhealthy and few people are willing to rent rooms in those areas. The city of Cotonou has actually 49% of tenants according to figures from the third census. Among the households surveyed, 22 are headed by women (14.7%) and 128 by men (85.3%). 106 out of the 109 owners live permanently their current home.

The smallest time spent in the area is 0 year and the longest one is 53 years. The average size of the households amounts to 5.59, thus about 6 persons per household. However, the average number of children and the average number of adult amount respectively to 2.37 and 3.22. The households head age ranges from 23 to 101 years. The average household head age amounts to 46.35, so about 46 years. Regarding to educational background, 19.3 % of the household heads do not go to school, 42 % have primary level, 28.7 % secondary level and 10 % university level.

The survey results show that 140 households have been at least once flood victims (93.3%). Thus, 120 households reported having suffered damages due to flooding and the remaining 20 households did not suffer damages. The damages which have been reported are: damage to property, evacuation of the house, health problems and loss of personal belongings.

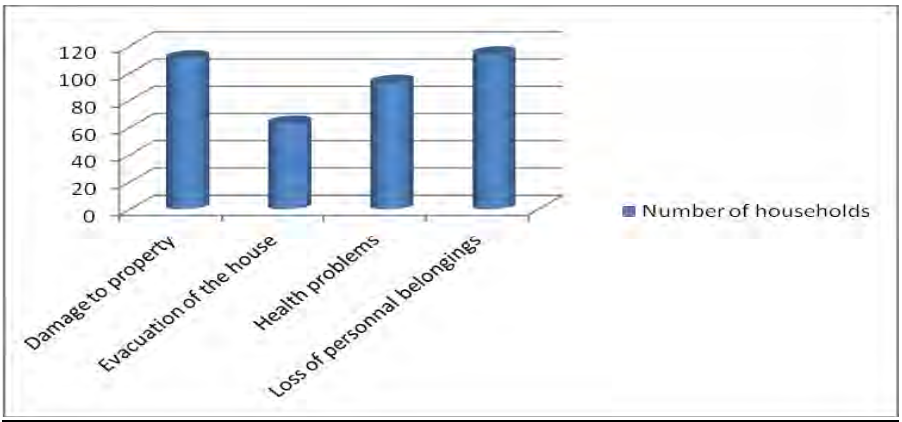

Figure 2 Kind of damages reported

A total of 101 households have estimated that the cost of damage is high and 9 households not high. Regarding information on the nature of the areas regarding flood, 98 households reported being aware of the existence of the risk before deciding to settle in the area (65.3%) while 52 households have answered the opposite (34.7 %). Thus, three households have got this information by chance and 95 by a voluntary request. 67 households living in areas at risk of flooding due to the flooding of Lake Nokoué and lagoon of Cotonou were surveyed against 83 for those who live in the swamps.

It was asked to the households a question about the maximal acceptable risk they expected by opting to remain in these areas at risk. The answers to this question showed that 36 households expect a recurrence of a flooding every year, 31 households once every two years, 19 households once every three years and 64 households once every four years or more than four years. These figures show that part of the population (36) has resigned to undergo annual flooding because for them floods are due to natural hazards. Indeed, the analysis shows that only 36 households are willing to bear the highest risk of a flooding every year, 31 once every two years, 19 once every three years and 64 once every four years or more than four years. But in Cotonou, the floods occur more than once each year (at least twice according to the location of the residence). These results indicate that people are exposed to a risk level that exceeds the one they were willing to tolerate. Among the factors that conditioned the installation of households in these risky areas, proximity to schools, shopping, workplace and transport ranks first (57 households). It is followed by financial factors, that means, the interesting prices of land and housing (42), and then legacy (28), and finally other factors (23). In the "other factors" category, they reported mainly that everybody should have his own house and to do not be at the mercy of the owners.

The maximal acceptable risk is estimated through an ordered multinomial Probit model. The descriptive statistics of the variables used for the estimation are presented in table 4.

Table 3 Descriptive statistics of the variables used

Variable	Obs	Mean	Std. Dev.	Min	Max
risqmaxi	150	2.26	1.239344	1	4
sexe	150	.8533333	.3549585	0	1
pro	150	.7266667	.4471636	0	1
pc	150	.38	.4870125	0	1
ff	150	.28	.4505031	0	1
inon	150	.4466667	.4988129	0	1
inf	150	.6533333	.4775028	0	1
pdvr	150	.7533333	.4325151	0	1
ins	150	.2733333	.4471636	0	1
tem	150	14.14	10.9875	0	53
hhsize	150	5.593333	2.999098	1	23
age	150	46.35333	14.52336	23	101
age2	150	2358.153	1517.633	529	10201

Estimations results are presented in the table 4.

Table 4 Résults of the ordered multinomial Probit

	Dependent variable : RISQMAX			
	Coefficients	Prob	Marginal effects	Prob
	Demographic variables			
SEXE	0.5999749**	0.022	-0.2358099**	0.018
HHSIZE	0.075128**	0.039	-0.0292719**	0.039
AGE	0.0835993**	0.019	-0.0325726**	0.019
AGE2	-0.000755**	0.021	0.0002942**	0.021
	Residential variables			
PRO	-0.7679133***	0.005	0.2779622***	0.002
TEM	0.0152004	0.120	-0.0059225	0.120
PC	-0.3172727	0.212	0.1240513	0.212
FF	0.0493	0.849	-0.0191604	0.849
INON	-0.3268911	0.184	0.1272855	0.181
	Variables of psychological control			
INF	0.7747853***	0.004	-0.3001444***	0.003
PDVR	-0.1638031	0.530	0.0631287	0.523
INS	0.624453***	0.008	-0.2303151***	0.004
Prob>Chi2	0.0002		Pseudo R-squared	0.1012

***, **, *: Significant respectively at 1%, 5% and 10% level.

The estimator of robust standard errors was used to overcome a potential problem of heteroscedasticity of errors of the model. The regression is overall significant, because Prob>Chi2 amounts to 0.0002 (significant at 1 %). The results are presented in Table 3.

Households whose heads are men are more willing to take flood risk than others, ceteris paribus. This result confirms the assumption that men are willing to take more risk than women, ceteris paribus. Eckel and Grossman (2008) argued that in most studies, women are found to be more averse to risk than men. The owners are not willing to accept more risk than the remaining households. This situation could be explained by the fact that the owners because of the investments they have made in their land do not want to be obliged to see the place impossible to live. Moreover, if the place becomes impossible to live, they will lose all their tenants, ceteris paribus. Being informed about the nature of the area regarding floods before the installation has a positive influence on the level of maximal acceptable risk by households. This could be explained by the fact that households because they have that information (i.e., they are aware about the real situation of the area toward flooding), accept a relative high level of risk. They are aware that the risk of flooding is the confrontation of two quantities: the hazard and vulnerability. Think it is good to backfill the flood-prone areas with all kinds of waste also has a positive impact on the level of maximal acceptable risk. Households, who have this perception of waste, think they can mitigate the adverse effects of flooding with them. Also, the household size positively influences the risk level. Thus, large households are willing to be exposed to more flood risk, due to the fact that it will be complicate for them to be able to find shelter in another areas with affordable prices. Household head age influences positively the maximal acceptable risk with threshold effect, i.e. the effect is nonlinear. Having the residence in the floodplain of Lake Nokoué or lagoon of Cotonou, the factors conditioning installation in the area, the opinion of households about the statement and the duration of the household within the area do not have effect on the maximal acceptable risk by households.

Conclusions, Recommendations, and Suggestions for Future Research

This study has focused on the analysis of the impacts of the floods on the households' welfare and of the maximal acceptable risk by households that are living the areas prone at risk of flooding. The study reveals that households are really affected by the negative consequences of floods. However, one has to notice that floods do not only affect negatively households' welfare.

The households living in flood-prone zones are exposed to risk level that is greater than the maximal risk they accept. Therefore, they should be protected in order to lessen their vulnerability to floods (strengthen their resilience). Ensure their protection could be through the construction of infrastructure that can act on the hazard of floods. However, one has to notice that the infrastructures cannot protect them against all kind of floods. Also, the solution will not be only to build such infrastructures, but also to attempt to move some households out of these areas that are prone to flood risk in order to restore the natural channel of rainfall waters circulation. Econometric analysis of the maximal acceptable risk is done through an ordered multinomial Probit model.

Future research could try to assess the positive impacts of floods on households' welfare since floods can improve the welfare of some kind of households and meanwhile decrease the welfare of the others. Also, the analysis that is done belongs to biophysical vulnerability analysis, and one has to improve that by doing the integrated assessment of households' vulnerability to floods in Cotonou.

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