FLOOD RISK ASSESSMENT IN DATA SPARSE REGIONS: THE USE OF QUESTIONNAIRES TO COLLECT HISTORIC FLOOD DATA – A CASE STUDY FOR THE RIVER MOUSTIQUES IN HAITI

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ABSTRACT

Flooding caused by storm surges, tropical storms and hurricanes causes severe damages in Haiti every year. When these inundations occur, the affected areas become inaccessible, preventing field work to register the flood water height and extent. High-resolution satellite imagery and aerial photography, on the other hand, are too expensive for a developing country like Haiti. The lack of this data results in a lack of adequate flood maps and models, making it impossible to predict the cost of the damages and take the right measures to minimise them. The information necessary to generate flood maps can, however, also be found in the knowledge of the inhabitants of the affected areas. These people remember if their house was flooded and if their properties were damaged due to flooding. Therefore, a questionnaire was drawn up and 294 households in the study area, the plain of the river Moustiques in the Northwest of Haiti, were questioned about the most recent and the most severe flood in their memory. In total, 19 different historic flood events were described in 347 answered questionnaires. This research aims to create flood maps by combining the coordinates of the house of each questioned person with the flood height they remembered. Furthermore, flood damage factors were generated from the questionnaires, in which the inhabitants indicated how much damage was caused by each inundation to their houses, crops, livestock and vehicles. The average damage percentages for houses show an increase when the flood height increases. For crops, livestock and vehicles, however, this increase is not visible. This can be due to the fact that these elements are not located in the same area as the houses of which the coordinates and flood height are used. The collected data can thus not be taken too literally, as the memory of people is not always correct. However, by combining this information with other geographic data of the study area, it is possible to create flood maps and damage factors in order to establish a flood risk assessment of a data sparse region against a low cost.

Keywords: flood risk, questionnaires, damage factors, Haiti

INTRODUCTION

Haiti, a small island state located in the Caribbean, was the first black republic to declare its independence in 1804. For the biggest part of the following two centuries, the country has known an instable political situation, hindering the economic and human development. As a result, Haiti is currently the poorest country of the northern hemisphere [1]. It is ranked 163rd of 188 countries in the 2015 Human Development Index of the UNDP [2]. This index represents the wellbeing of the population in reference to the life expectancy, the degree of education, and the Gross National Income (GNI) of a country. Not only scores Haiti merely 0.493 on a scale of 0 to 1, the island state continues to drop in the overall ranking, losing 14 places in comparison to the Human Development Index of 2009 [3]. In 2017, the country was ranked 17th in the INFORM (Index For Risk Management) Global Risk Index. This list identifies the countries with the highest overall risk of a humanitarian crisis, including the risk of human and natural hazards, vulnerability and lack of coping capacity [4].

The topography of the island state is characterised by high and steep mountains. 63% of the countries surface has a slope of 20% or more [1]. Combined with Haiti's location in the Hurricane Belt, the area with the highest occurrence rate of tropical storms and hurricanes worldwide, this leads to an extreme vulnerability towards storm surges and flooding. The EM-DAT database has registered 40 flood events and 30 storm events in Haiti from 1998 until now [5], leading to a total of 7680 deaths and more than 3.5 million people affected. While this and other databases provide general disaster information on national level, there is a lack of detailed information on the exact locations of these events and the damages they have caused.

Traditionally, this location-specific flood data can be acquired by field work, registering water heights and extents and corresponding damages during the flood event, or can be derived from high-resolution satellite imagery or aerial photography. Both methods, however, have important disadvantages. While the former technique is often not applicable, since the affected areas are inaccessible during a flood, the latter is too expensive for a developing country such as Haiti. Due to the lack of input data on historic flood events, adequate flood maps and models that predict future inundations and damages, and aid in allocating the most efficient measures to the high-risk areas, are non-existent for most of Haiti's water systems. This research investigates the possibilities of a third group of input data, the knowledge of the inhabitants of the affected areas. With the use of questionnaires, the people of a flood prone area are questioned on historic flood events and the corresponding damages to their own properties.

STUDY AREA

The catchment of the river Moustiques is located in the northwest of Haiti. It has a total area of 222 km² and a population of 40,000 people [1]. The river rises from the mountain massif *Massif de Terre Neuve*, and flows into the *Baie des Moustiques*, a bay at the *Canal de la Tortue*, the sea canal between the northern Haitian mainland and the island *Île de la Tortue*. The study area of this research is the plain of the catchment, surrounding the mouth of the river, covering a surface of about 20 km², as shown on Figure 1. Three villages are located in the area: Baie des Moustiques, Nan Ti Charles and Augustin. All households of these villages were included in the research.

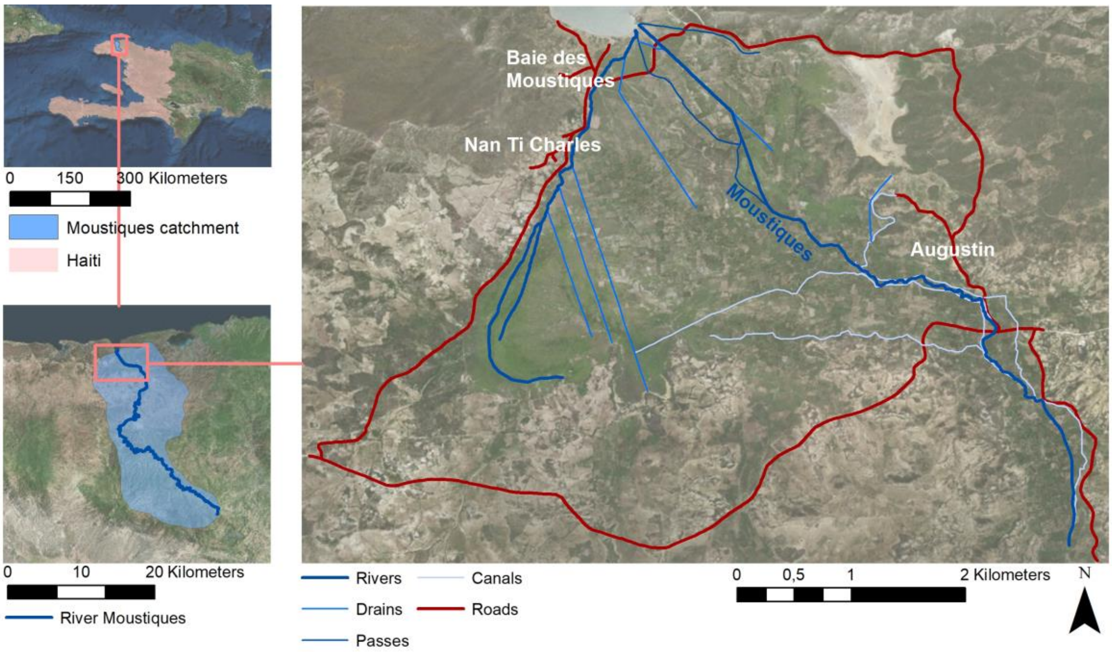


Figure 1: Overview of the study area: the plain of the catchment of the river Moustiques, located in the northwest of Haiti

METHODOLOGY

The research can be divided into three phases: the preparation, the field work and the post processing. During the first phase, the questionnaire was drawn up and then translated. In January 2018, the second phase took place. During 6 days, 6 local inhabitants conducted the surveys of 294 households. Finally, the results of these questionnaires were digitalised and analysed.

The questionnaire that was drawn up, is divided into six sections. In the first section, general information is gathered on the questioned and his residence. Then, information on the household, number of people and their age is inquired in the second part. Section 3 deals with the possession of vehicles and section 4 with the agricultural activities of the household. Possession of livestock and possession of farmland are questioned here. The final two parts of the questionnaire inquire into the knowledge on historic flood events. In section 5, the height and duration of the most recent flooding in the memory of the questioned is gathered, as well as the corresponding damages to house, vehicles, livestock and farmland. Section 6 is drawn up with the same questions, but concerns the most severe flooding in the knowledge of the questioned. All questions were drafted in French, and then translated by the local partners in Haitian Creole [6].

In January 2018, 6 trained pollsters conducted the surveys during 6 days. All 294 households in the three villages were questioned. 71 of them were located in Nan Ti Charles, 164 in Baie des Moustiques and the remaining 59 in Augustin. While all 294 questioned inhabitants answered section 5 on the most recent flood event, only 53 of them also recollected a more severe flood event, which led to 347 descriptions of 19 different historic inundations.

In the last phase of the research, the collected data was digitalised and organised in a database table. Using the GPS coordinates of the houses, acquired while conducting the surveys, a GIS shapefile of the buildings in the villages was generated. All other data from the questionnaire was joined with this geographic data.

In the survey, the respondents were asked to indicate the flood height of a flood event using a figure of a person. The different options for the water height were the ankle, knee, thigh, navel, armpit, shoulder and head. Furthermore, they could indicate that there was no water in the house during the flooding, or that the water level went over the head. In the analysis phase, these water heights were linked to the degree of damage to their house, as indicated in the questionnaires. Here, the questioned could chose four options: no damage, small damages, large damages or complete destruction of the building. With this information, a percentage of damage to residential buildings was calculated for every flood height.

For the calculation of damage factors for vehicles, farmland and livestock, two situations were compared. First, the number of vehicles and livestock, as well as the area of farmland, owned by the questioned, was calculated for a non-flooded situation, based on the information given in the general information sections. Then, these numbers were combined with the number of animals that have died, vehicles that were damaged and the degree of damage done to crops for every flood event described. These results were used to draft flood damage factors for crops, livestock and vehicles.

Finally, for every described flood event, the height of the inundation was linked to the location of the house, where the survey was conducted. These water heights will be combined with a DEM (digital elevation model) of the area to create a historic flood maps. However, existing open source DEMs have a spatial resolution of 30m, which is too low to generate an adequate historic flood map [7,8]. Therefore, aerial photography, performed during the field work in January 2018, is used to create a high-resolution model of the study area. This process is still ongoing, and, thus, the historic flood map has not yet been created.

RESULTS

In a first step of the analysis, the general household information is processed. In total, 1,868 people live in the study area, of which 945 men and 923 woman. Baie des Moustiques is the largest village in the plain, with 1040 inhabitants and an average of 6.34 people per household. Augustin has the highest average of people per household, 7.11 to be specific, and a total population of 420. Finally, Nan Ti Charles has 408 inhabitants and an average of 5.75 people per household. In Table 1, an overview of the number of people per household is given per sex, per age and per village.

Then, the GPS locations, gathered in the questionnaires, are used to create a GIS shapefile of the residential buildings in the study area. Figure 2 shows a map of the 294 buildings, per village. All other acquired data is linked to this geographic data. Each point on the map contains the information of that household, as well as the flood height of one or two historic flood events and the corresponding damages.

Table 1: Overview of the number of people in the plain of the river Moustiques, Haiti, for the villages Nan Ti Charles, Baie des Moustiques and Augustin [6]

	Nan Ti Charles		Baie des Moustiques		Augustin	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Children (<15y)	85	74	230	201	91	71
Adults (15y-64y)	117	117	290	293	104	137
Seniors (<64y)	9	6	13	13	6	11
Total	211	197	533	507	201	219

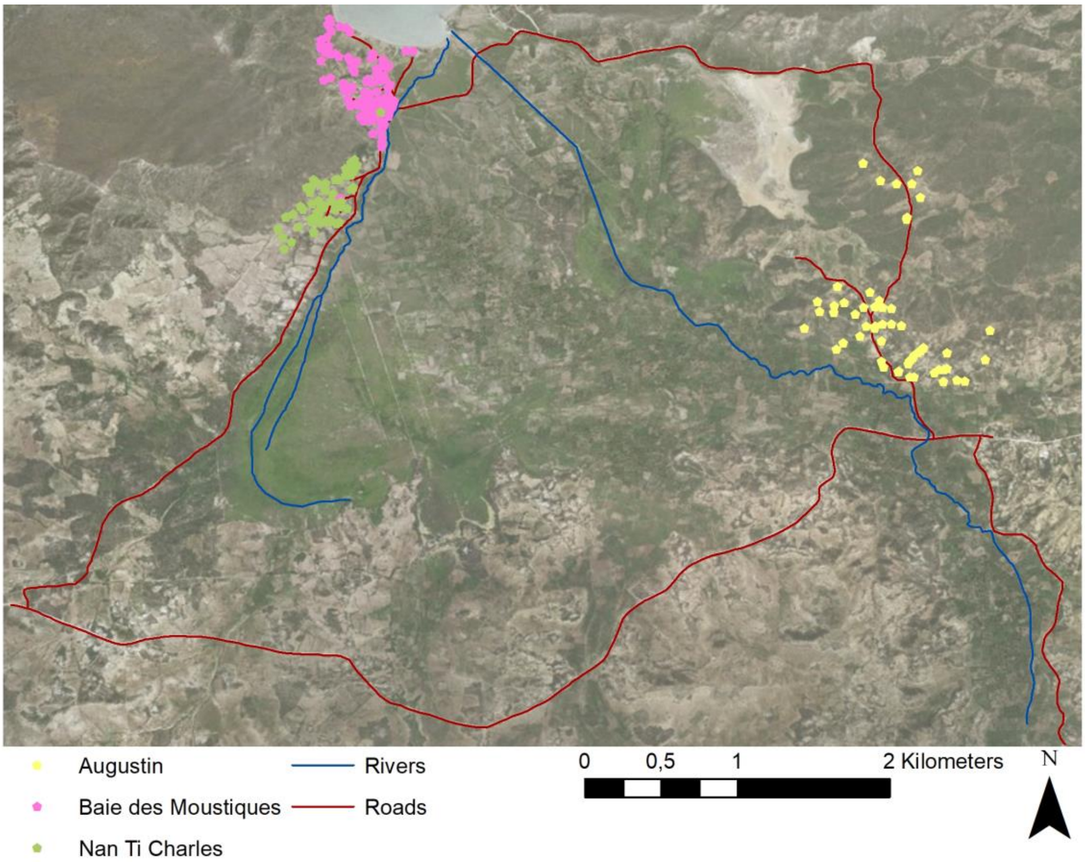
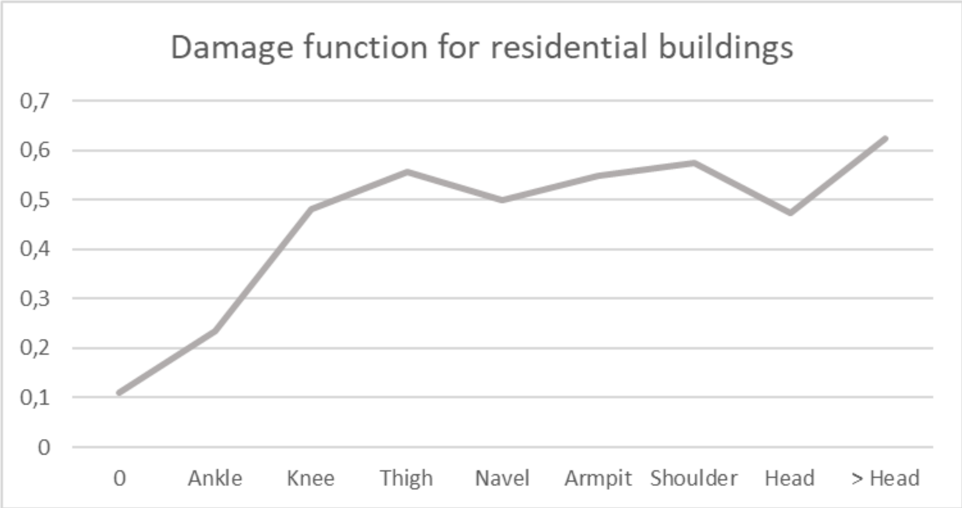


Figure 2: Location of residential buildings in the plain of the catchment of the river Moustiques, Haiti, based on the coordinates acquired by questionnaires, conducted in January 2018 [6]

In Graph 1, the damage factors for buildings, based on the water levels and corresponding damage degrees gathered during the surveys, are shown. The graph shows on overall upward trend, indicating a linear relationship between the degree of damage to a residential building and the water level. However, there are a few small peaks visible on the graph. These can be explained by the uneven distribution of the number of flood events per water height. While 201 questioned people described a flood with a water level ‘head’, there were only 9 described inundations with a water level ‘knee’ and 9 with a water level ‘thigh’. The damage factor for the ‘head’ water level will thus be a lot more averaged than the factor for the other water levels.



Graph 1: Damage function for residential buildings in the plain of the catchment of the river Moustiques, Haiti. The vertical axis shows the degree of damage to the building, while the horizontal axis displays the water level.

For the other elements at risk, the drafted damage functions did not show any trend. For vehicles, this can be explained by the very low number of households that possess a vehicle. Only 1 household in the study area owns a car, 17 own a motorcycle and 4 own a boat. Furthermore, 58 households possess one or more horses that they use for transport, 109 animals in total. In the most recent flooding, in January 2018, the car was not damaged, but 4 motorcycles and 2 boats were. Of the 109 horses, 19 did not survive the inundation. While these numbers include all vehicles in the entire study area, and are thus representative, they are too low to create adequate damage factors per water level.

Although there was sufficient information on crops and livestock, the drafted damage functions did not have the expected result as there was no trend visible. All data on flood damages is linked to the GPS locations of the questionnaires. The acquired flood heights are thus the water levels as observed in the houses. However, the farmlands are located in the centre of the plain. The animals are also kept in these fertile grass areas, and not near the villages. Therefore, there is no relationship between the water level and the damages to farmland and livestock, as these are not in the same location. Nonetheless, the analysis of the damages to these agricultural activities has shown that these elements are highly affected by flooding. 227 people of the 294 questioned have livestock. Only 22 of these households did not lose any animals during the flooding of January 2018. On the other hand, 62 of them have lost all livestock. In total, 58 % of all animals in the study area have died during this inundation. An overview of the damages to the crops can be seen in Table 2. In total, the damage percentage for crops is 72.25% for the flooding of January 2018. Shallot and plantain are the most vulnerable for inundation, with the highest damage factors, followed by corn and beans. These four crops are not only the least resilient to flooding, but are also the most cultivated in the study area. Banana and manioc have a much lower damage factor, but are also less cultivated. These damage percentages, for farmland as well as for livestock, clearly show the high impact of flooding on the rural study area. Therefore, a flood map will be created for the entire plain. Then, the generated water levels in the centre of the plain can be linked to the acquired damage degrees and adequate damage functions can be drafted.

Table 2: Overview of the damage percentages for the crops in the plain of the river Moustiques, Haiti, after the flooding in January 2018. The second colom shows the number of households that own farmland with this type of crop [6].

Crop	Number of households	Damage percentage (%)
Corn	178	67.69
Beans	168	62.24
Plantain	156	78.00
Shallot	129	85.93
Banana	59	36.95
Millet	52	42.01
Sweet potato	41	48.67
Manioc	32	35.19
Others	9	25.00
Total		72.25

CONCLUSION

This research is based on the results of a survey, conducted in January 2018 with 294 households. The questioned inhabitants were asked for general information on their household, as well as their knowledge of the most recent flooding and the most severe flooding in their memory. This input data is subjective, as the memory of a person is not always an accurate and objective recollection of the event. However, several studies have shown that this form of 'citizen science' is valuable, certainly in areas where other historic data is inexistent [9,10]. Since all households in the villages in the study area were inquired, the output data is representative and, if analysed with the necessary care, also accurate.

The generated damage function for residential buildings shows a clear upward trend, which indicates that higher water levels lead to higher damage degrees. However, due to the uneven distribution of the number of data per water height, the graph does show a few peaks. Therefore, a quantitative approach will be used when incorporating these damage factors into an assessment. Different degrees of damage will be linked to a certain water level, rather than using the specific percentages.

The first analysis of the questionnaires clearly indicated the high impact of flooding on the agricultural activities in the rural study area. 58% of the livestock was killed by the flooding of January 2018 and 72.25% of the crops were damaged during that same inundation. Therefore, future research will focus on a methodology to create adequate, quantitative damage degrees that are linked to different water levels. These will lead to clear flood damage maps that can be used to educate and sensitise the local inhabitants to protect their animals and crops from future flooding.

An important step in this future research is the development of a flood map for the area based on the flood heights, linked to the house locations in the villages. These water levels can be combined with a high-resolution DEM of the area to generate a flood map for the entire plain. Then, this map can be used as input to generate damage degrees and perform a damage assessment for the area. Although there is still a lot of research to be done, the first analysis of the questionnaires shows promising results in developing a low-cost and accurate methodology to gather historic flood data in data-sparse areas.

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