THE FLOOD RISK IN THE LOWER GIANH RIVER: MODELLING AND FIELD VERIFICATION

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ABSTRACT. - The flood risk in the lower Gianh River: modelling and field verification. Problems associated with flood risk definitely represent a highly topical issue in Vietnam. The case of the lower Gianh River in the central area of Vietnam, with a watershed area of 353 km^2, is particularly interesting. In this area, periodically subject to flood risk, the scientific question is strongly linked to risk management. In addition, flood risk is the consequence of the hydrological hazard of an event and the damages related to this event. For this reason, our approach is based on hydrodynamic modelling using Mike Flood to simulate the runoff during a flood event. Unfortunately the data in the studied area are quite limited. Our computation of the flood risk is based on a three-step modelling process, using rainfall data coming from 8 stations, cross sections, the topographic map and the land-use map. The first step consists of creating a 1-D model using Mike 11, in order to simulate the runoff in the minor river bed. In the second step, we use Mike 21 to create a 2-D model to simulate the runoff in the flood plain. The last step allows us to couple the two models in order to precisely describe the variables for the hazard analysis in the flood plain (the water level, the speed, the extent of the flooding). Moreover the model is calibrated and verified using observational data of the water level at hydrologic stations and field control data (on the one hand flood height measurements, on the other hand interviews with the community and with the local councillors). We then generate GIS maps in order to improve flood hazard management, which allows us to create flood hazard maps by coupling the flood plain map and the runoff speed map. Our results show that: the flood peak, caused by typhoon Nari, reached more than 6 m on October 16th 2013 at 4 p.m. (its area was extended by 149 km²). End that the typhoon constitutes an extreme flood hazard for 11.39%, very high for 10.60%, high for 30.79%, medium for 31.91% and a light flood hazard for 15.32% of the flood area.

Keywords: Gianh River, Floods, Modeling, Water level

1. INTRODUCTION

Floods, which are one of these risks, cause the most human and material causalities in the world. This is particularly true of the typhoons in Vietnam where two thirds of the territory is on the littoral area with a rich hydrographic network (e.g. the Red river, the Gianh River and the Mekong River). These factors increase the risk of floods in Vietnam.

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The center of Vietnam (more precisely the watershed of the Gianh River) has been subjected to flood risks in the last decade, and the economic and social consequences have an unprecedented magnitude in Vietnam. Every year, there are from two to three floods affecting the Quang Binh province (for example, two floods in October 2013, which are considered two of the biggest floods in the country's history). Furthermore, in Vietnam, there is no research on the Gianh River and flood management is poorly understood. Therefore, there is a need for knowledge of the flood hazard in the watershed and of the social vulnerability so as to contribute to better risk management.

The goal of this article is to determine where the flood areas are located, by using a simulation based on the flood of 2013 to create a flood hazard map. This map can help to improve the knowledge of risks in order to diminish the vulnerability of flood areas and improve crisis management.

2. THE STUDY SITE: THE LOWER COURSES OF THE WATERSHED OF THE GIANH RIVER IN CENTRAL AREA OF VIETNAM

The watershed of the Gianh River is situated to the north of Quang Binh in the center of Vietnam and it is the biggest river in the province. According to the reports from the Natural Resources and Environment Department of the Quang Binh Province, the main stem of the river has a length of 158 kilometers with a basin of 4 680 km² (58% of the province and among them the lower river with an area of 353 km^2). Its source is in the Copi highlands in the north-west of the Quang Binh province (Fig. 1). The watershed of the Gianh River presents a rich and complex hydrographic network. In the mountainous areas, precipitation is between 2 500 mm to 2 800 mm per year, from 1 600 mm to 1 800 mm in the plain and September, October and November are the months when most of the floods in the studied zone occur. The Gianh River contains three major tributaries: the Rao Tro River, which has a length of 68.5 km, the Rao Nam River (86

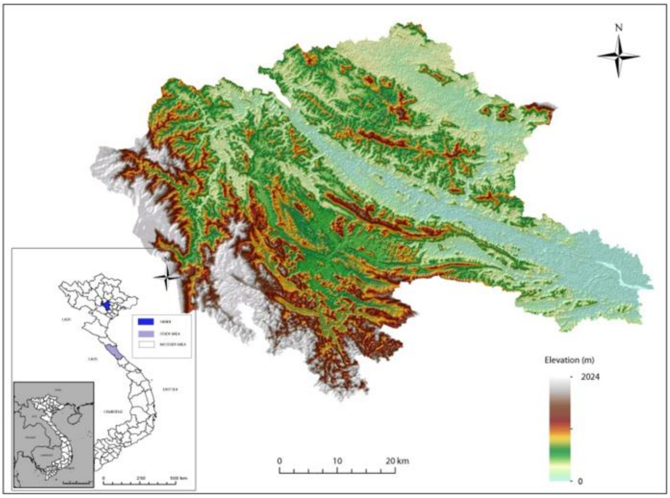

Fig. 1. ***Geographical location and the topographic map of the study area***

km) and the Son River with 84 km. The total debit rises to more than four billion m³/year for the Gianh River and nine billion m³/year in the watershed.

The watershed topography of the Gianh River is very complicated. It presents three very distinct topographic forms: the mountain, the valley and the plain.

This mountainous area contains the Copi highlands to the west as well as the Truong Son highlands. The valleys have an altitude from 5 to 20 meters and the plains have an altitude from 0 to 4 meters (Atlas Vietnam, 2010). During the rainy season, this area is always confronted by the flood phenomenon due to the overflow of Gianh River. Furthermore, upstream of the Gianh River, the slope flow is more significant (more than 6%) on the two-thirds of the length of the River, then diminishes in the delta. However, the slope flow is less significant downstream (less than 2%) so during the flood, the flowing speed is lower.

The rich hydrographic network and the topography are aggravating factors of the risk of flood in the watershed (Stéphanie. D, 2010). The use of hydrodynamic modeling is necessary in order to know the flood hazard.

3. DATABASE AND WORK METHOD

3.1. The database

The topography data: In this research, DTM is created using 10m of contour line. DTM is processed through ArcInfo and ArcView. This processed topographic data is provided as an input to hydrodynamic model MIKE 21 to determine the flood plain (Ahmad, 1999). The cross sections were issued from the Natural Resources and Environment Department of the Quang Binh Province: 20 cross sections on the Gianh River, 10 on the Son River, 4 on the Rao Nan River and 6 on the Rao Tro River. They are used in the one-dimensional model MIKE 11.

The hydrologic data was obtained from the Ministry of Natural Resources and Environment in the 8 hydrometric stations (Tan My, Ba Don, Phuong Lap, Tan Lam, Mai Hoa, Rao Nam, Dong Tam and Tuyen Hoa). Only 2 stations (Dong Tam and Tan Lam) measured the flow. In fact, we only have the flow data on the Gianh River from the Dong Tam station from 1960 to 1980; and the Rao Tro River from the Tan Lam station from 1970 to 1980. Based on the rainfall data from the hydrometric stations, using GIS, we can calculate the rainfall of the floodplain on the Gianh River and using the rainfall and evaporation data, and we can calculate the flow using the hydrologic model "MIKE NAM" in order to use them as boundary conditions in the one- dimensional model of MIKE 11. The flows at the Dong Tam station on the Gianh River from 1960 to 1980 and at the Tan Lam station from 1972 to 1980 on the Rao Tro River are used to validate this model. Furthermore, using this model, we can reconstruct the data of the flow at each station to accommodate our research.

3.2. The hydraulic modelling under Mike Flood

Application of 1D modelling: the hydrological networks in the Gianh River watershed are described in a hydraulic diagram which includes the Gianh River with 20 cross sections, the Tro Rao River with 6 cross sections, the Rao Nan River with 4 cross sections and the Son River with its 10 cross sections.

Application of 2D modelling: The limit of the flood plain is determined by the topography map associated with the documents on the historic flood, in order to cover the entire flood plain. The topography data is processed through ArcInfo and ArcView. The topographic data is provided as an input to the hydrodynamic model Mike 21 (Ahmad, 1999). The boundary conditions are fully taken into account by the 1D model.

Coupling the 1D and 2D models**:** MIKE FLOOD is used to couple the 1D and 2D models. According to the reports from DHI in 2015, coupling these two models allows us to use the best qualities of each, avoiding or reducing the disadvantages encountered using them separately, and MIKE FLOOD offers the opportunity:

- To represent the runoff in the minor river bed by a 1D model perfectly suited to topographic cross sections type of data;
- To represent the overflow of the minor river bed to the flood plain by lateral links
- To represent the runoff in the flood plain in a 2D model by providing a detailed description of the fields of speeds and flooding heights;
- To generate mapping directly under a GIS.

Validation of the model on the flood in 2013: The water levels measured at Mai Hoa and Ba Don from the typhoons Wutip and Nari are very important in comparing the calculated water level and the observed water level to validate the model. In this model, the coefficient NASH is 0.759 in comparing to Mai Hoa hydrometric station.

Moreover the model was calibrated and verified using field control data (on the flood heights measurements), and through the interviews with the community and with the local councillors (140 measuring point and interviers) from a realistic program in 2015. The highest level of the flood calculated in the model matches the measurement and interviewed data. Also, according to the data interviewed from the community, counsellors and reports from Quang Binh Province's Center of Flood, Storm Control and Rescue, in October 2013, there were 2 floods resulting from the Wutip and Nari typhoons.

In consequence, regarding the compared data above, we can validate the model.

4. RESULTS

4.1 Water level

On 30th September and 16th October 2013, the typhoons Wutip and Nari accompanied by huge rainfall in the province caused a terrible flood on the Gianh River and Quang Binh Province. This disaster caused 15 deaths and 250 million euros of damages. They were considered the two worst typhoons ever in the Province. The water on the Gianh River flooded the watershed community. According to the model's result:

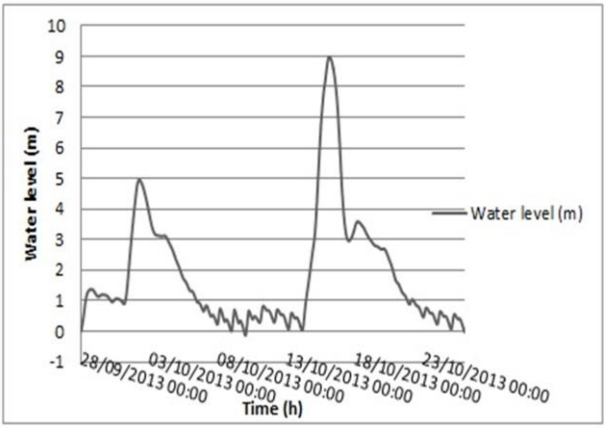

Fig. 2. ***The Water level at Mai Hoa station***

At Mai Hoa station, there were 2 peaks caused by typhoon Wutip and Nari. According to the peak's model, the flood's peak occurred at around 16 o'clock on 16th October 2013 due to typhoon Nari. The water level calculated at Mai Hoa station (on the upstream) was 9 m (Fig. 2).

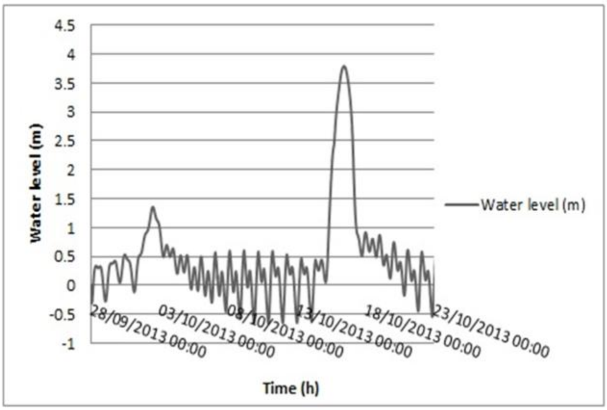

Fig. 3. ***The Water level at Ba Don Station***

On the downstream, at Ba Don station, rain started in the morning of 30th September with over 250mm/ day during Wutip, on 15th October with 200mm/day, and went up to 550mm/day during typhoon Nari. The flood's peak was calculated at 3.7m at around 21 o'clock on 16th (Fig. 3).

Due to this geographic location, the watershed of the Gianh River is always affected by hurricanes and floods. It results in a lot of human and materiel losses. Furthermore, the data from the Natural Resources and Environment Department of Quang Binh Province shows that since 2005, the number of typhoons in Quang Binh has been rising (Fig. 4).

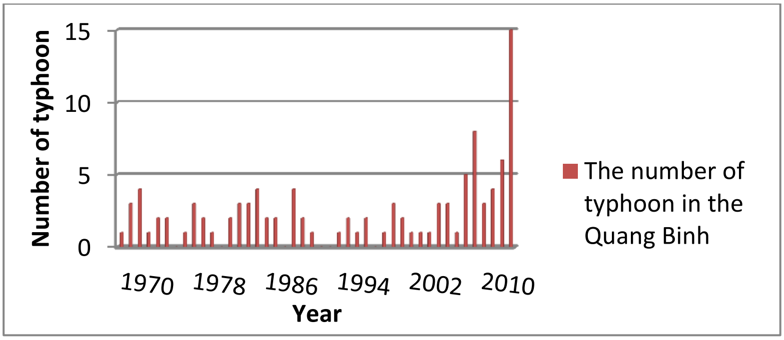

Fig. 4. ***The number of typhoon in the Quang Binh from 1970 to 2013***

4.2. Flood hazard

Based on this model, we can calculate the flow velocity and flood level in the floodplain.

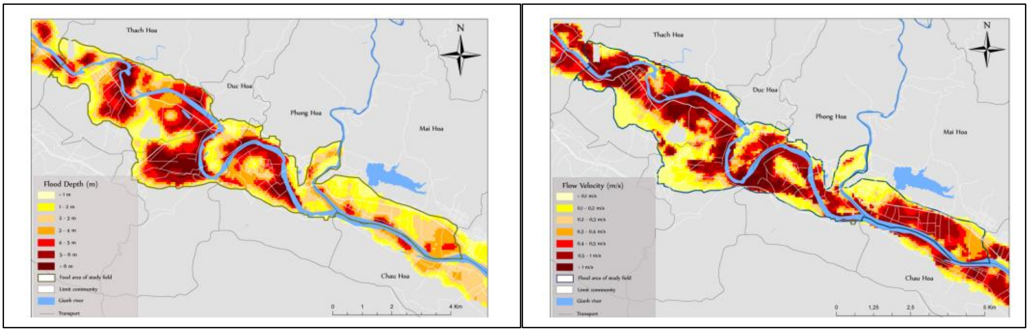
Fig. 5. ***The depth of flooding and flow velocity on the upstream of the Gianh river to Nari typhoon in 2013 (Huu Duy, 2015)***

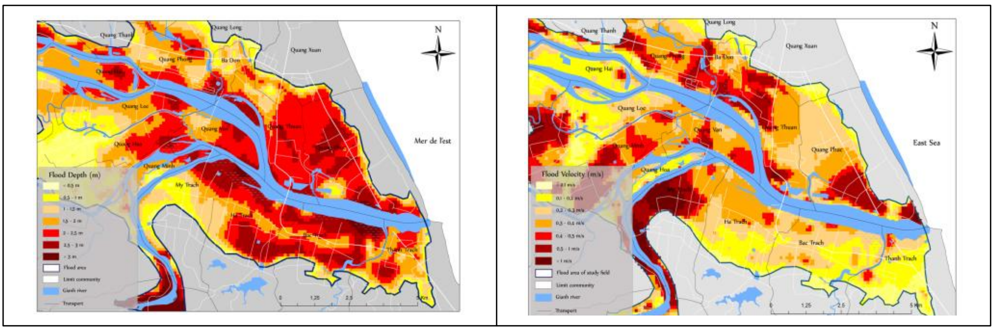
Fig. 6. ***The depth of flooding and flow velocity on the downstream of the Gianh river to Nari typhoon in 2013 (Huu Duy, 2015)***

Due to the complex topography and the rich hydrographic network, the flood was very large on the upstream: there was a place where it was recorded as 6m (at Thach Hoa, Duc Hoa anh Phong Hoa Community) and the other Community was flooded from 1 to 4m (Fig. 5). On the downstream, the depth of the flood was lower than on the upstream; the deepest place was 3,2m at Bac Trach, Ha Trach and My Trach Community and a large area on the downstream was flooded from 1 to 2,5m (Fig.6). According to the data from the interview which the Agriculture and Rural Development Department of Quang Binh Province, the Wutip and Nari hurricanes decreased Quang Binh's economical activities for four years. Fig 7 and 8, show the flood area of the seven Communities in the upstream and twenty-seven Communities in the downstream.

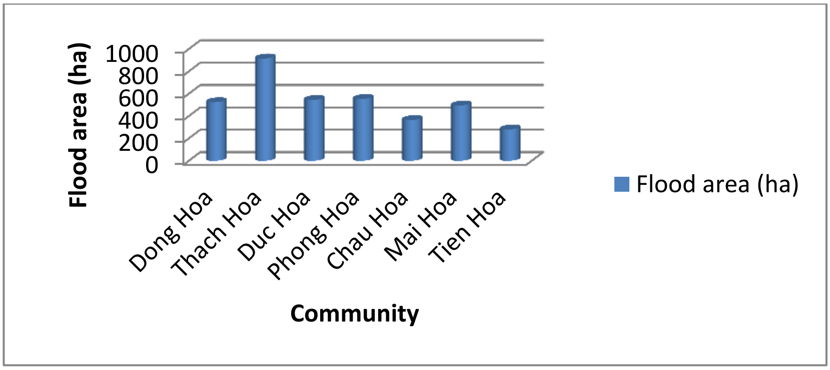

Fig. 7. ***Flood area by each community in the upstream of the Gianh River from Nari typhoon in 2013***

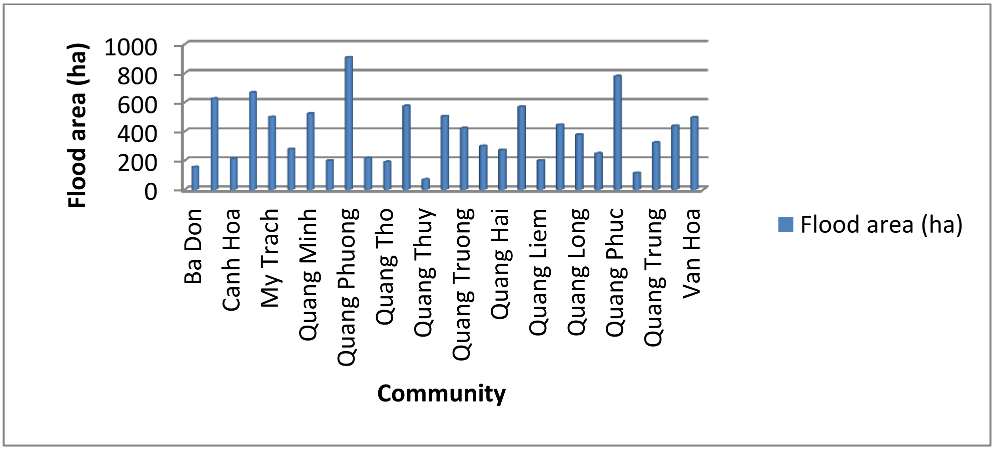

Fig. 8. ***The flood area of the Community in the downstream from the Nari typhoon in 2013***

To highlight the potential flooded areas, a map of the flood hazard was established to analyze the risk of floods in the watershed (Fig. 9).

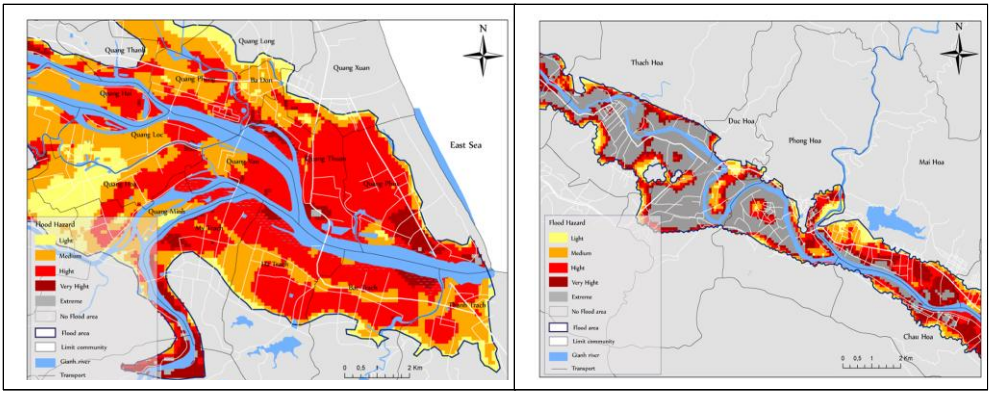

Fig. 9. ***Flood hazard in the downstream and upstream of the Gianh River from typhoon Nari in 2013***

Table 1. ***Flood hazard in the watershed of the Gianh River from typhoon Nari in 2013***

	Flood hazard area (ha)	%
Light	2281.91	15.32%
Medium	4753.78	31.91%
High	4586.89	30.79%
very high	1579.02	10.60%
Extreme	1696.91	11.39%

5. CONCLUSIONS

In the past years, Mike Flood modeling has been developed to apply to the flood hazard. In the studied area, floods have caused the most human and material damage, which is more serious in a context where typhoons are more frequent since 2005.

A simulation of the flood phenomenon determines the floodplain during the flood in October 2013 and shows the characteristics of floods in the watershed. Because of the topography, water levels upstream are higher than downstream (over 6 m in the upstream against more than 3 m in the downstream). Floods constitute an extreme flood hazard for 11.39%, a very high for 10.60%, a high for 30.79%, and a medium for 31.91% and a light for 15.32% of the flood area.

It is an effective and necessary informational tool to help decision makers develop a floodplain by, for example, not starting new construction and not increasing the number of people in the high hazard zone in order to reduce vulnerability (Provence-Alpes-Côte d'Azur, 2010), as well as integrating the management of water resources for safety (Beilicci, E and Beillicci, R, 2014). In addition, we can also use the parameters of this model for other similar flooding.

In addition, we can create a risk map using a vulnerability and hazards map. It is essential in forming methods to protect and minimize risks during floods. However, we will introduce this research in a subsequent article.

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