3rd International Conference - Water resources and wetlands. 8-10 September, 2014 Tulcea (Romania);
Available online at http://www.limnology.ro/wrw2016/proceedings.html
Editors: Petre Gâștescu, Petre Bretcan; ISSN: 2285-7923; Pages:177-183; Open access under CC BY-NC-ND license

VULNERABILITY AND FLOOD RISK MANAGEMENT IN THE LOWER GIANH RIVER

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ABSTRACT
Problems associated with flood risk definitely represent a highly topical issue in Vietnam. The case of the lower Gianh River in the Central region of Vietnam with an area of 353 km² which is regularly subject of flood risks, whose the scientific question is strongly linked to flood risk management and the evaluation of the vulnerability to limit its risks. In this study, flood risk are defined as the product/result of the hydrological risk of an event and the damages related to this event. They are determined by the combination between the hazard and the vulnerability. Furthermore, as a developing country, Vietnam often confronts to the rarity of lands. The urbanisation has encroached on agricultural lands situated in highly exposed areas, which raises the vulnerability. In view of this, this article presents first of all the first approaches of the vulnerability in the lower Gianh River to identify, characterize and organize into a hierarchy the spaces to spread the vulnerability. Then, the second part is about the flood management to orientate the risk prevention policy and to help decision makers develop a floodplain for urban planning and to reduce vulnerability of the area which are based on the risk map and the flood hazard. In addition, the vulnerability in the flood areas was caused by the flood of 2013. The area where the vulnerability is very high increased from 1656 ha in 1989 to 4453 ha in 2013, from 178 ha in 1989 to 947 ha in 2013 in high, from 8259 ha to 8520 ha in medium, and decreased from 1691 ha to 243 ha in low and from 2905 ha to 1354 ha in very low. With floods of 2013 constituted an extreme flood hazard for 11.39%, a very high for 10.60%, a high for 30.79%, a medium for 31.9% and a light for 15.32% of the flood area. Moreover, the urbanized area increased by 200 ha from 1989 to 2013 in the extreme flood hazard area; by nearly 200 ha in the very high hazard area and 800 ha in the high hazard area. Besides, according to the risk map of 2020 of twenty-seven Communities in the downstream and seven Communities in the upstream in the flood area caused in 2013: 2138 ha of the territory will be in the very high risk area, 5886 ha in the high risk area, 2766 ha in the average risk area, 1369 ha in the low risk area and 111 ha in the very low risk area.

Keywords: floods, Gianh river, hazard, risk, vulnerability

1 INTRODUCTION

In Vietnam, flood is one of these risks which causes most of the human and materials damages. It becomes a more and more threatening issue in the watershed of the Gianh river in Central Vietnam. The hazard and precipitation are particularly serious, and happen in a very short time in this area. According to the reports from the Natural Resources and Environment Department of the Quang Binh Province, the rainfall regularly exceeds 700 millimeters in 24 hours for the most intense events. Every year, there are about four to six typhoons affecting the Quang Binh province (for example, two typhoons in October 2013, which are considered as two of the biggest typhoons in the country history, which caused more flooding). This type of disaster is particularly induced by high vulnerability. «The vulnerability is the conditions as a whole determined by factors or physical process, social, economic or environmental that increase the sensitivity of a collectivity to the impact of hazards» (Nations Unies, 2005, p.1). «A propensity to damage or dysfunction of different exposed elements (well, people, activities, functions, systems) incorporation of a territory and a data society» (Léone and Vinet 2006). «The vulnerability is as damage that undergoing an issue, either as the propensity of the issues to undergo this damage» (D'Ercole 1994).

In the classical analysis, the risk is associated with the hazard and vulnerability (Veyret and Reghezza 2006). These spaces are anthropized despite the presence of regular natural hazards. The territory is a social construct (Zaninetti et al., 2014), where it is important to know the vulnerability and flood hazard.

The goal of this article is approaching the vulnerability in the lower Gianh river to identify, characterize and organize into a hierarchy the spaces to spread the vulnerability. On the other hand, it determines the flood management in order to orientate the risk prevention policy and to help decision makers develop a floodplain for urban planning as well as reducing vulnerability of the area which is based on the risk map and the flood hazard.

1.1 Vulnerability approach in the lower course of the river Gianh

The watershed of the Gianh river has a surface of 4680 km², while the surface of the lower course counts 353 km². The main course has a length of 158 km. The watershed of the Gianh river presents a rich network and complex hydrography, in a mountainous area where the precipitations exceed 2500 mm a year.

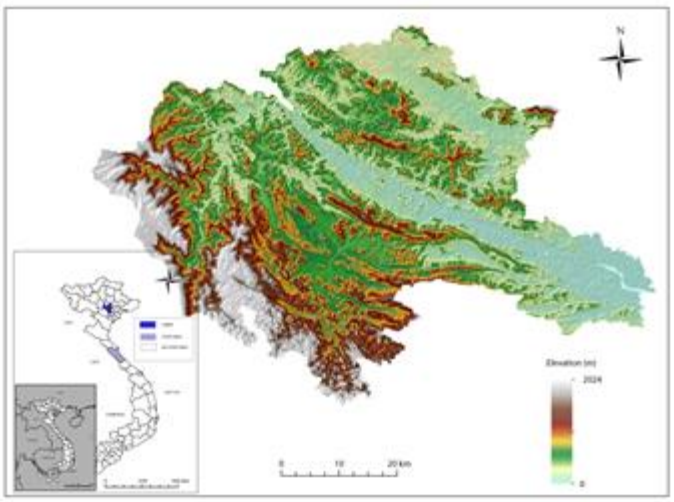

Figure 1. Geographical location and the topographic of the study are

The topography of the watershed of the Gianh River is composed of three very different topographic forms: mountains, valleys (from 5 to 20 m) and plains (from 0 to 4m). The slope flow is more significant (more than 6%) on the two-thirds of the length of the river, then diminishes in the delta. On the other hand, the slope flow is less significant downstream (less than 2%). Thus it is subjected to natural disasters, for example, floods. During the past years, floods have caused most of the human and material damages, as in 1993, 1996, 2007 and 2013. During the floods in 2013, there were 15 deaths and damages amounted to 250 million euros. Limits of the current management are very important. The dynamic analysis consists of superimposing the static mapping of the land use previously established, in order to apprehend, in a better way, the spatiotemporal evolutions by characterizing the nature and the speed of the changes.

1.2 The land use: evolution of the land use from 1989 to 2013

The consequences of flooding (in Vietnam generally and particularly in the watershed of the Gianh river) are also the results of the growth of the urbanization. The evolution of the use of the grounds (for example, urbanization or fish farming in the late 1989) increased the vulnerability of these areas. In this part, we can show the territorial dynamics in the flood-risk area produced by the flood of 2013. First of all, the original facilities were mainly designed for rice growing, whereas these spaces are more dynamic today (demographic growth, urbanization and industry). The table below indicates the evolution of land use in the flood-risk area of the watershed from 1989 to 2013. Seven thematic classes were listed: agricultural areas, fruit trees areas, urbanized arebelas, woody areas, fish farming areas, water areas and unused ground areas. However, in this study, we did not analyze the evolution of water areas and unused ground areas.

Table 1. Land use in the flood in the Gianh river from 1989 to 2013

	Year					
	1989		2003		2013	
	ha	%	ha	%	ha	%
Urban	1656.55	9.23	2894.66	16.04	4453.67	24.2
Agricultural	8259.94	46.04	9305.23	51.58	8520.62	46
Fish	178.31	0.99	703.24	3.89	947.48	5.13
Fruit trees	1691.56	9.42	264.93	1.46	243.06	1.31
Forest	2905.92	16.19	1899.09	10.52	1354.12	7.34

Between 1989 and 2003, the rice areas increased from 8259.94 ha (which is 46.04% of flood-risk area) to 9305.23 (that is 51.58%). However, because of the urbanization growth policy and fishing activity, the surface for growing rice decreased from 9305.23 ha to 8520.62 ha between 2003 and 2013. The area to grow fruit trees decreased too, from 1691.56 to 264.93 ha in the same period of time, and were replaced by rice areas which continued to decrease between 2003 and 2013 (from 264.93 ha to 243.06 ha).

The urbanized areas increased sharply: After the renewal in the country in 1986, the economic liberalization and the opening of Vietnam entail the replacement of land use types in agricultural areas by industrial areas, residential buildings (Bernier et al., 2007). In the floods, urbanized areas increased from 1656.55 ha in 1989 (that is 9.23% of the flood-risk area) to 2894.66 ha in 2003 (16.04% of the flood-risk area). It continued to increase up to 4453.67 ha (that is 24.2%) in 2013 because it is a time of economic and urban development.

The striking fact on the map of the land use in 1989 is the extent of woody areas, which then covered 2905.92 ha (16.19% of flood area in the lower course of the river). In 2003, the forest covered only 1899.09

ha (that is 10.52%). Afterward, the surface of forest continued to decrease quickly to cover only 1354.12 ha (7.34%) in 2013. Between 1989 and 2003, the fish areas increased significantly, from 178.31 ha (0.99%) to 703.24 ha (3.89%) and then increased again up to 947.48 ha (5.13%) in 2013.

1.3 The vulnerability: a quick increase in the zone of study

In this study, the vulnerability is determined by the damage criteria. According to the analysis in the first part regarding the flood-risk area of the watershed of the Gianh River, it reveals urbanized areas, agricultural areas, fish farming areas but also woody areas.
We defined the following classes:

- Urbanized areas, where:

The collective housing is characterized by large sets of buildings at height. This zone is little vulnerable. However, the density of population there is very strong. The individual housing, where the density is less than in the previous areas. However, in this area, all the properties are situated at ground level.

The infrastructures of leisure activities (school, parks) are vulnerable especially during the periods of attendance. The infrastructures of transportation are very vulnerable: through the watershed of the Gianh river, there are several networks of important transportation. They connect the North and the South of Vietnam, such as the international road 1A, 12A and the railroad.

-Fish farming areas: the aquacultural activities are present all along the Gianh River, which is actually the most affected sector by the flood and the storms. The aquacultural areas are less urbanized compared with the agricultural area, however the costs are much more expensive than rice growing and market gardening.

- Agricultural areas: we divided agricultural areas into two parts: rice area (and market gardening) and fruit trees area. In the watershed of the Gianh River, a large surface is covered by rice growing, thus the damages are much more important there than in fruit trees areas. Furthermore, fruit trees' growing is more resistant that rice growing and market gardening.

- Woody areas: forests are mainly composed of mangrove swamps. Every year several surfaces of mangrove swamps are destroyed (according to the data of studies) because of the typhoon and the flood. However, on the Gianh River, the surface of mangrove swamp is not very important and the cost is thus not very expensive: that is the reason why the vulnerability is low in terms of damage.

In this study, the vulnerability maps are realized by the criteria we defined which are presented on the picture underneath.

Type of land use	Vulnerability
Urbanized areas	Very Hight
Fish areas	Hight
Agricultural areas	Medium
Fruit trees ares	Light
Forest areas	Very Light

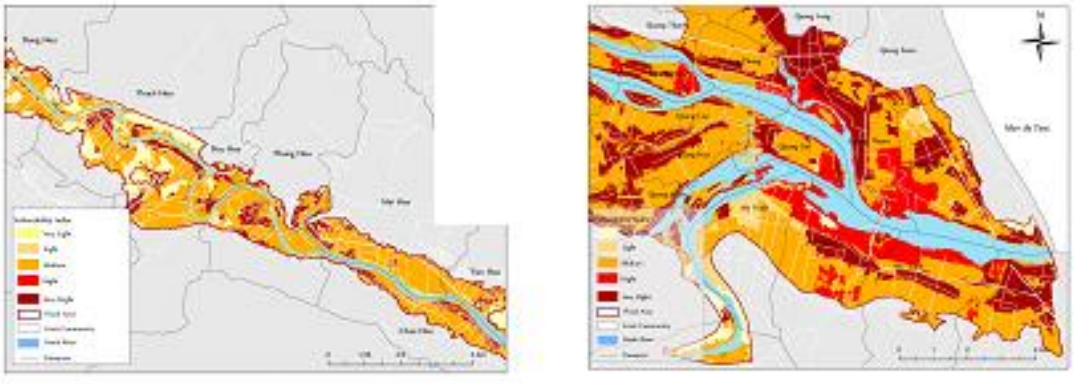

Figure 2. For example, the vulnerability map in 2013 (Nguyen et al., 2016)

The vulnerability in the flood-risk area was caused by the flood of 2013. Between 1989 and 2013, the very high vulnerability area increased by 2797.12 ha, by 769.17 ha in high vulnerability area and 260.68 ha in medium vulnerability area. It decreased by 1448.5 ha in low vulnerability area and to 1551.8 ha in very low vulnerability area.

The spatial vulnerability map of the territory results from the analysis of the criteria of damage. It allows us to differentiate the vulnerability of places only by spatial data alone. This analysis makes a combination with the hazard which is an obvious interest in the planning of the territories, and constitutes a multi-hazards approach which is fairly uncommon in the risk studies.

2 WHAT IS THE MANAGEMENT OF FLOOD RISK?

2.1 Hazard flood: A tool to manage the impacts of floods

The land used in the lower Gianh river is a combination of two primary functions: habitation and agriculture. The villages are located along the riverside and the low interstitial land is used for rice cultivation. Moreover, people living in the vicinity are exploiting the fish resources daily. Floods are recurrent during the last 25 years, the populated areas were flooded four times: in 1993, 1995, 2007 and 2013. In order to deal with this recurrent risk, the Quang Binh provincial authority has adopted the strategies against flooding e.g. building dikes Bebon with height of 2.5 m at the estuary of the Gianh River, and cultivate mangroves. However, in Quang Binh Province generally and in the watershed of Gianh River particularly, there is not a certain solution for managing the effects of flood on human and agriculture.

On 30th September and 16th October 2013, the typhoons Wutip and Nari accompanied by huge rainfall in this province resulted in a terrible flood on 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 Gianh River flooded the watershed community.

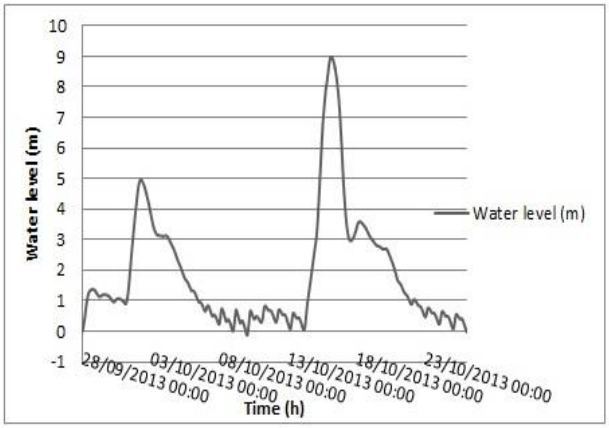

Figure 3. The Water level at Mai Hoa station

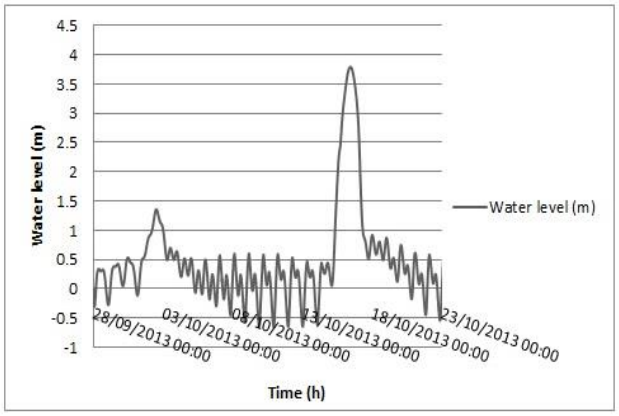

Figure 4. The Water level at Ba Don station

At Mai Hoa station, there were 2 peaks caused by the typhoons Wutip and Nari. According to the peak's model, the flood's peak occurred at around 16:00 on 16th October 2013 due to the typhoon Nari. The water level calculated at Mai Hoa station (on the upstream) was 9 m (Figure 3.).

On the downstream, at Ba Don station, during the Wutip typhoon, the rain started in the morning of 30th September with over 250mm/ day. On 15th October, the rain was measured 200mm/day and went up to 550 mm/day during the Nari typhoon. The flood's peak was calculated at 3.7m at around 21:00 on 16th (Figure 4.).

The establishment of the flood hazard map in the Lower of Gianh river which is based on the map of the flood and the flow velocity from a hydrodynamic model (Nguyen et al., 2016) as well as on-field verifications (measurements of water levels in the mission in 2015) and streamflow forecasts and inundation water levels play key roles in the issuing of early flood warnings and in evacuation plans aimed at reducing damage (Saavedra-Valeriano and al, 2009). The typology of the natural hazard helps to draw up a map that distinguishes the following levels:

- Low: these places are submerged 0 to 1m with a speed of lower than 0.5 m/s;

- Medium: these places are submerged 0-1 m and a speed of between 0.5 to 1 m/s and 1 to 2 m and a speed of below 0.5 m/s;
- High: this level represents the depth of 1m or lower with the high speed and the depth from 1 to 2 m with a speed of 0.5 to 1 /s or depth from 2 to 3 m with low speed;
- Very high: these areas has a high velocity with depth from 1 to 2 m and a speed of 0.5 to 1 m/s with depth of from 2 to 3 m and a low speed with height from 3 to 4 m;
- Extreme: this level represents the peak of flooding. These places situate in the upstream of Gianh river.

According to the figure, we showed that the hazard is high for the area with low topography and where the depth of flooding is between 2-3 m downstream and 4 to 6m upstream. This area can be affected by high flood with high speed and a long duration of submersion.

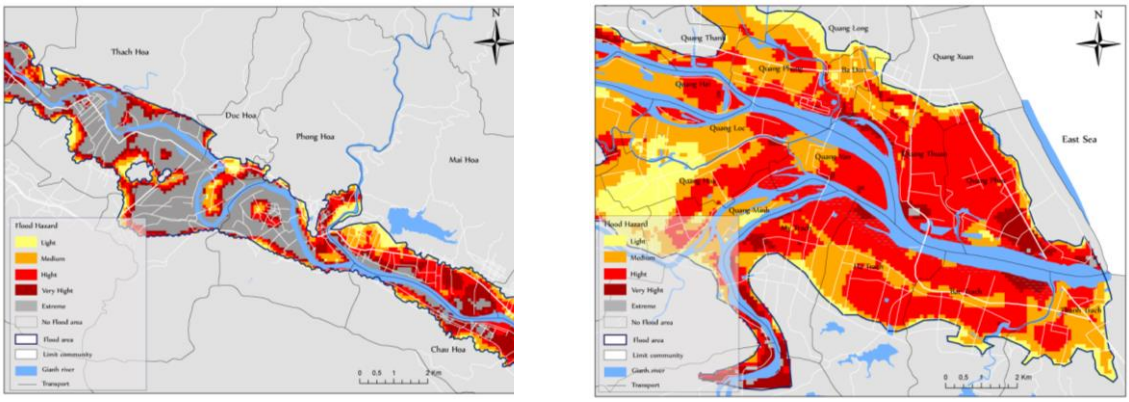

Figure 5. Flood hazard in the downstream and upstream of the Gianh River from typhoon Nari in 2013

The floods in 2013 constituted an extreme flood hazard for 11%. Its location, the extreme hazard is upstream watershed in three communities: Phong Hoa, Duc Hoa and Thanh Hoa where we could find the high deep flood with high speed. A very high of 11%, a high of 31%, a medium for 32% and a light of 15 % of the flood area (Figure 5.).

And thanks to the map of flood hazard, we can calculate the types of land uses that have been advanced in the area of the hazard of flooding. A large agricultural area is in the extreme hazard, very high and high areas.

In addition, the urbanized area increased in all flood hazard areas. The area increased by 200 ha from 1989 to 2013 in the extreme flood hazard area, by nearly 200 ha in the very high hazard area, 800 ha in the high hazard area and 800 ha in the medium hazard area. This increase is in the context of development of urbanization and demographics throughout Vietnam (Figure 6.). However, poorly planned urbanization or controlled may further aggravate the risk of flooding due to inappropriate changes in land use (Jha et al., 2011).

The urbanization of the field of study entails consequences located in the flood zone, which also depends on the men's resilience. Flood prevention is a crucial tool through which populations exposed can be prevented early enough to save lifes and goods (Jha et al., 2011). And the flood management via a hazard map can guide risk prevention policies and to help policymakers develop a floodplain of urban planning and reducing vulnerability.

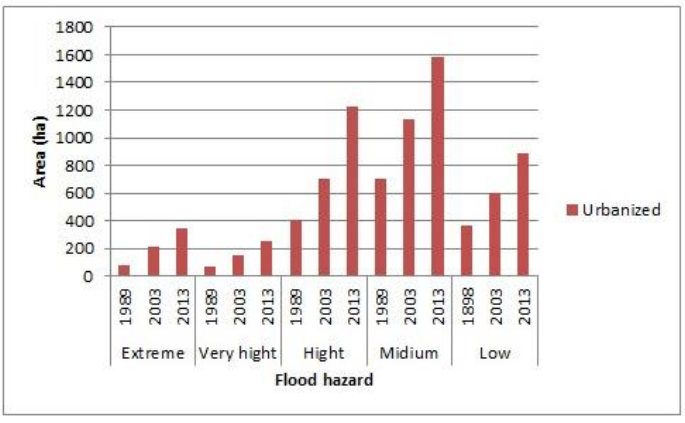

Figure 6. The evolution of urban area in the flood hazard area

2.2 The prevention of risk in the lower section of Gianh river

Viet Nam in general and the watershed of Gianh river in particular have been often affected by catastrophic elements within the past two decades, it has led the Government to reinforce the policies against floods in order to reduce the vulnerability of people and property. However, in Vietnam, there is not

any risk map for the prevention of flood and also for the service of management of territory.

Therefore, one of the objectives of this study is to propose the cartographic tools for flood prevention and flood risk control in decisions for management and development of the territory, particularly, for the orientation of development of the watershed in the future (in 2020). Nevertheless, because of the difficulties in obtaining data, we only realize the risky map for seven villages in upstream and 27 villages in downstream of the river.

«The influence of rising from 0 to 1m means that over 1m of water, the damage is the same for 2 or 3m of water» (Joyeux, 2004). Therefore, the type of risky categories permits to obtain a current map of the risk of flood in the watershed, distinguishing the following levels:

The very high risk areas correspond to the grave flood because of characteristics of flood flows, of velocity of flow, with a very high vulnerability.The high risk areas correspond to the grave flood as the very high risk areas; however, vulnerability in this case is medium and high (rice cultivation and fish farming).

The medium risk areas: these areas depend on the type of vulnerability. For example, the high hazard in the area of weak vulnerability (the fruit trees) or very light (the forests), so it causes the medium and light risk as we mentioned above, the fruit trees and the forests have a capacity of very strong resistance. Or, in the case of rice fields and fishing area that have a capacity of weak resistance, so despite of the light hazard, the risk is medium. The light risk areas correspond to light vulnerability. In addition, there is a growth between light hazard with a very high vulnerability (the urbanized area) and high hazard with a very light vulnerability. Urbanized areas, and spaces devoted to agricultural production (agriculture and fish farming) tend to favor the vulnerability of the territory to flood risk and increase risk with the rapid development of these planning. Besides, according to the risk map for 2020 of twenty-seven communities in the downstream and seven communities in the upstream in the flood area caused in 2013: 2138 ha of the territory will be in the very high risk area, 5886 ha in the high risk area, 2766 ha in the average risk area, 1369 ha in the low risk area and 111 ha in the very low risk area (Figure 7.).

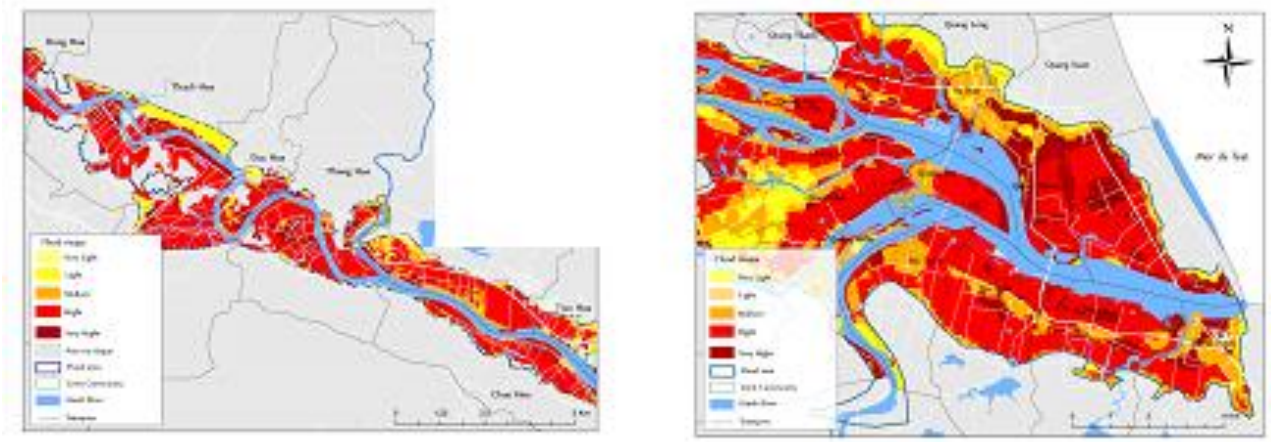

Figure 7. Risk maps in the Lower Gianh river in 2020

According to flood risk maps, we can delineate the areas where applicable prohibitions and preventive measures, protection and backup exist. In those areas where the risk is higher for the safety of human and property, the objectives are (Mottet and Rochel 2008):

- Prohibition of all new buildings
- Improving the safety of people and not increasing the number of people exposed
- Reducing the vulnerability of buildings and existing facilities with the requirements.

For this area is the most exposed because of water levels or speeds reached and the flood expansion fields. Those areas where the risk is low to medium can accommodate in urbanized areas, subject to compliance requirements or prevention, new construction.

3 CONCLUSIONS

In the past years, floods have caused a lot of human and material damages, which is more serious in a context where typhoons have been more frequent since 2005. In the process of economic and social

development, urban areas have increased rapidly, nearly 3000 ha between 1989 and 2013, while forest areas reduced almost 2000 ha during the same period. Urbanization encroaches on agricultural lands in highly exposed areas which increases vulnerability.

The vulnerability in the flood areas was caused by the flood of 2013. The area where the vulnerability is very high increased from 1656 ha in 1989 to 4453 ha in 2013, from 178 ha in 1989 to 947 ha in 2013 in high, from 8259 ha to 8520 ha in medium, and decreased from 1691 ha to 243 ha in low and from 2905 ha to 1354 ha in very low. With floods of 2013 constituted an extreme flood hazard for 11.39%, a very high for 10.60%, a high for 30.79%, a medium for 31.9% and a light for 15.32% of the flood area. Moreover, the urbanized area increased by 200 ha from 1989 to 2013 in the extreme flood hazard area; by nearly 200 ha in the very high hazard area and 800 ha in the high hazard area. Besides, according to the risk map of 2020 of twenty-seven Communities in the downstream and seven Communities in the upstream in the flood area caused in 2013: 2138 ha of the territory will be in the very high risk area, 5886 ha in the high risk area, 2766 ha in the average risk area, 1369 ha in the low risk area and 111 ha in the very low risk area.

It is an effective and necessary informational tool for flood prevention, implementing protective measures, and helping 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 the vulnerability of people and property, as well as integrating the management of water resources for safety (Beilicci and Beillicci 2014). In addition, we can also use the parameters of this model for other similar flooding.

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