

# CALCULATING AND BUILDING INUNDATION MAPS CORRESPONDING TO FLOOD FREQUENCIES IN GIANH RIVER BASIN

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**Abstract:** Gianh is the largest river basin in Quang Binh province with the flood season lasts about four months, from August to November. The number of floods and their magnitude vary widely by the years and from upstream to downstream of the river. This article presents a set of inundation maps corresponding to flood frequencies of 1%, 2%, 5%, 10%, 20% in the Gianh river basin. The results show that flooding happens more frequent in both river banks and downstream areas of Gianh river basin. As Gianh River runs mainly along Tuyen Hoa District, the communes along the river banks of the district are seriously affected by floods. The article also presents a calculated inundation area and inundation rate of the area of districts in the Gianh river basin, corresponding to flood frequencies of 1%, 2%, 5%, 10%, 20%.

**Keywords:** Flood, flood frequency, inundation maps, inundation area.

## 1. Introduction

Quang Binh is one of the central coastal provinces of Viet Nam with very complex climate and terrain. The province is the most affected by natural disasters; tropical cyclones, floods and flash floods occurring with high frequency and severity. Typhoons and floods usually occur from September to December, concentrated in October and November. Tropical cyclones lead to heavy rain and high tides, resulting in floods over the lowland and flash floods over mountainous areas. Other forms of natural disasters such as early floods (“Lũ tiểu mãn” or “Lũ đầu mùa” in Vietnamese) often occur from April to June every year. There are about two or three floods occur in Quang Binh every year, in average.

Natural disasters affect severely socio-economic development and human life. In Viet Nam, prevention of natural disasters and early warning systems for natural disasters are still limited, especially in the provinces that are frequently and directly affected by the disasters such as Quang Binh province.

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Therefore, the Viet Nam Red Cross (VNRC) and German Red Cross (GRC) aim at piloting a new approach called Forecast Based Finance (FBF) that uses forecast-based thresholds to automatically release money that pays for pre-planned short-term emergency preparedness actions in the critical window of time after a forecast but before a disaster.

To achieve that goal, the GRC and the Center for Meteorology and Climatology - jointly signed a research contract entitled: “Disasters Profile of Quang Binh Province and Review and Assessment of the Availability and Usage of Early Warning System and Weather Forecasts” with one of the objectives of this contract is to analyze the Disaster Profile of Quang Binh Province with focus on heavy rains and floods.

This article, is extracted from the contract’s outcome, calculates and builds inundation maps corresponding to flood frequencies of 1%, 2%, 5%, 10%, 20% in Gianh river basin. Also to present the inundation area by inundated depths (0-1 m, 1-2 m, 2-3 m, 3-4 m, 4-5 m, 5-6 m, 6-7 m, >7 m) across the basin and the area and inundation rate of the area of districts in the Gianh river basin, corresponding to flood

frequencies of 1%, 2%, 5%, 10%, 20%.

## 2. Data and methodology

Data used in this article are observed water levels of hydrological stations of Dong Tam, Mai Hoa and Tan My with different periods of 1976-2015, 1980-2015, and 1974-2015 respectively.

GIS method combined with survey uses meteo-hydrographical data and topographic maps to identify potential flood areas, and then combined with survey data to develop the flood inundation map for study area. This is a simple method which satisfy the calculation of flood inundation under scenarios with the frequency for Gianh river basin.

At present, the flow measurement data series of the rivers in Quang Binh are neither

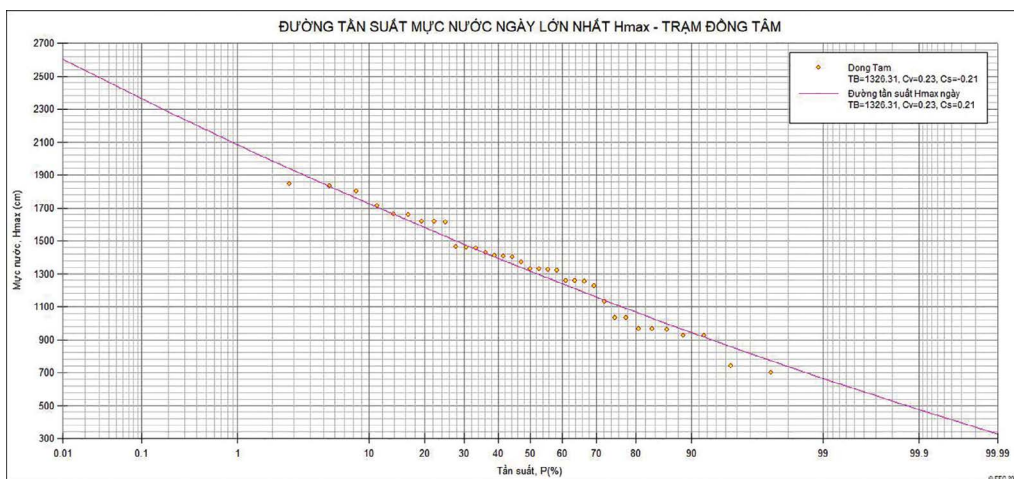
complete nor long enough. Therefore, instead of flow data, the highest water levels corresponding to frequencies 1%, 2%, 5%, 10%, 20% and the 10x10 DEM topographic map combined with the survey were used to develop a flood map for the Gianh, Kien Giang river basins with the given frequencies.

The implementing steps are as follows:

*Step 1: Editing and processing water level data at hydrological stations in Gianh river basin.*

*Step 2: Calculate the water level corresponding to the frequency of 1%, 2%, 5%, 10%, 20%.*

- The highest water level value in a year was selected basing on the water level datasets at the stations; then



**Figure 1. The maximum water frequency at Dong Tam station in Gianh river**

- Creating theoretical frequency lines by Pearson type III (PIII) method for water level at monitoring stations on Gianh river (See Figure 1 for example).

- Based on “theoretical frequency lines” to determine the water level at the stations

corresponding to the frequency of 1%, 2%, 5%, 10%, 20%.

Calculation results of the water levels corresponding to the frequency of occurred floods at the stations are shown in Table 1.

**Table 1. Calculated water levels (cm) corresponding to the flood frequencies for stations on Gianh river**

Hydrological Stations	Frequency ( P%)				
	1	2	5	10	20
Dong Tam	2082.93	1986.82	1845.76	1723.53	1579.38
Mai Hoa	965.31	853.18	703.76	588.76	470.21
Tan My	211.60	198.12	179.85	165.46	150.22

Step 3: Develop flood map with frequency of 1%, 2%, 5%, 10%, 20%.

Using digital maps combined with the topographic maps 10x10 DEM to create flooding maps with frequencies of 1%, 2%, 5%, 10%, 20%. Then:

Based on topographic maps to determine the area and level of flooding in flooded areas.

Step 4: Investigating, identifying the flooding traces of floods that have occurred, and the location of flooding in relation to the frequency.

Step 5: Correct the flood maps with the frequencies of 1%, 2%, 5%, 10%, 20% after surveying.

### 3. Results and discussion

#### 3.1. Inundation map corresponding to the frequency of 1%

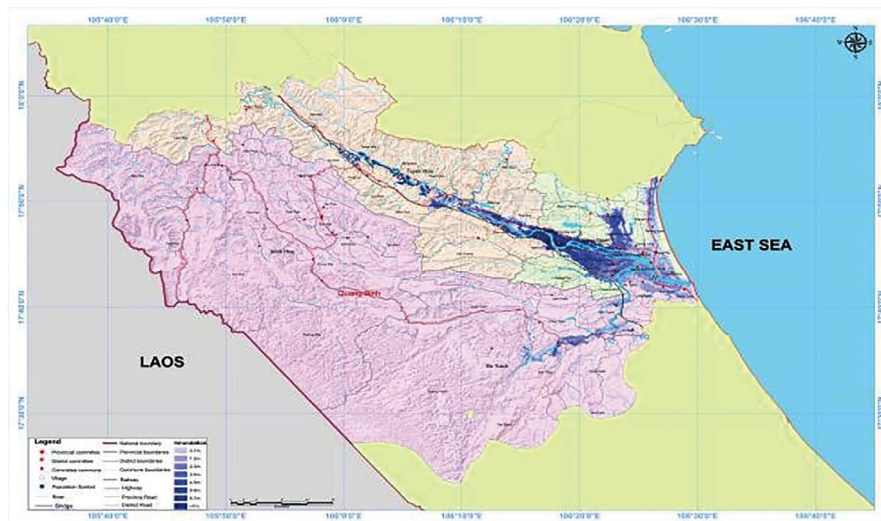
The calculated results of inundation in Gianh river basin corresponding to flood frequency 1% are presented in Table 2 and Figure 2.

**Table 2. The area (km<sup>2</sup>) and percentages (%) of inundation in the districts of Gianh river basin with a frequency of 1%**

No.	District	Inundated depth								
		Total	0-1m	1-2m	2-3m	3-4m	4-5m	5-6m	6-7m	>7m
1	Bo	60.04	32.06	18.73	6.17	2.36	0.61	0.11	0.00	0.00
	Trach	2.83	1.51	0.88	0.29	0.11	0.03	0.01	0.00	0.00
2	Quang	119.90	34.93	15.26	22.27	20.20	15.32	5.95	3.88	2.09
	Trach	19.53	5.69	2.49	3.63	3.29	2.50	0.97	0.63	0.34
3	Tuyen	49.95	12.34	5.10	6.10	6.13	6.11	4.85	5.42	3.88
	Hoa	4.35	1.07	0.44	0.53	0.53	0.53	0.42	0.47	0.34
Total		229.89	79.33	39.09	34.54	28.69	22.04	10.91	9.31	5.97

The calculated results of inundation in the Gianh river basin shows that, with the frequency of 1%, about 229.89 km<sup>2</sup> in Gianh river basin was

submerged, of which about 79.33 km<sup>2</sup>, 39.09 km<sup>2</sup>, and 34.54 km<sup>2</sup> were deeply inundated from 0-1 m, 1-2 m, and 2-3 m depth respectively.



**Figure 2. Inundation map corresponding to the frequency of 1% on Gianh river basin**

### 3.2. Inundation map corresponding to the frequency of 2%

The calculated results of inundation in Gianh

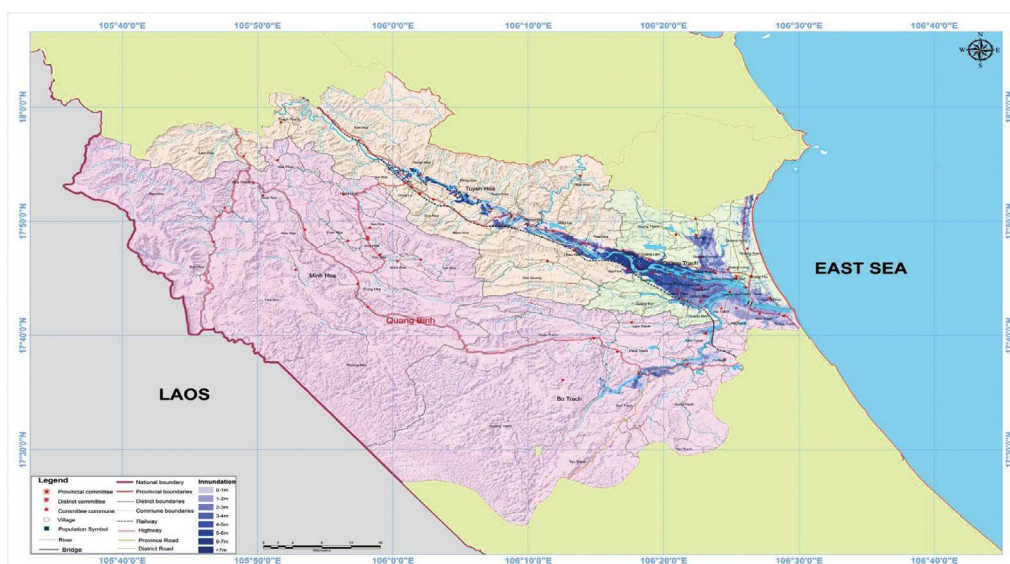
river basin corresponding to flood frequency 2% are presented in Table 3 and Figure 3.

**Table 3. The area (km<sup>2</sup>) and percentages (%) of inundation in the districts of Gianh river basin with a frequency of 2%**

No.	District	Inundated depth								
		Total	0-1m	1-2m	2-3m	3-4m	4-5m	5-6m	6-7m	>7m
1	Bo	60.04	32.06	18.73	6.17	2.36	0.61	0.11	0.00	0.00
	Trach	2.83	1.51	0.88	0.29	0.11	0.03	0.01	0.00	0.00
2	Quang	119.90	34.93	15.26	22.27	20.20	15.32	5.95	3.88	2.09
	Trach	19.53	5.69	2.49	3.63	3.29	2.50	0.97	0.63	0.34
3	Tuyen	49.95	12.34	5.10	6.10	6.13	6.11	4.85	5.42	3.88
	Hoa	4.35	1.07	0.44	0.53	0.53	0.53	0.42	0.47	0.34
Total		229.89	79.33	39.09	34.54	28.69	22.04	10.91	9.31	5.97

The calculated result of inundation in the Gianh river basin shows that, with the frequency of 2%, about 180.88 km<sup>2</sup> in Gianh river basin was submerged, of which about

62.75 km<sup>2</sup>, 42.07 km<sup>2</sup>, and 21.74 km<sup>2</sup> were deeply inundated from 0-1 m, 1-2 m, and 2-3 m depth respectively.



**Figure 3. Inundation map corresponding to the frequency of 2% on Gianh river basin**

### 3.3. Inundation map corresponding to the frequency of 5%

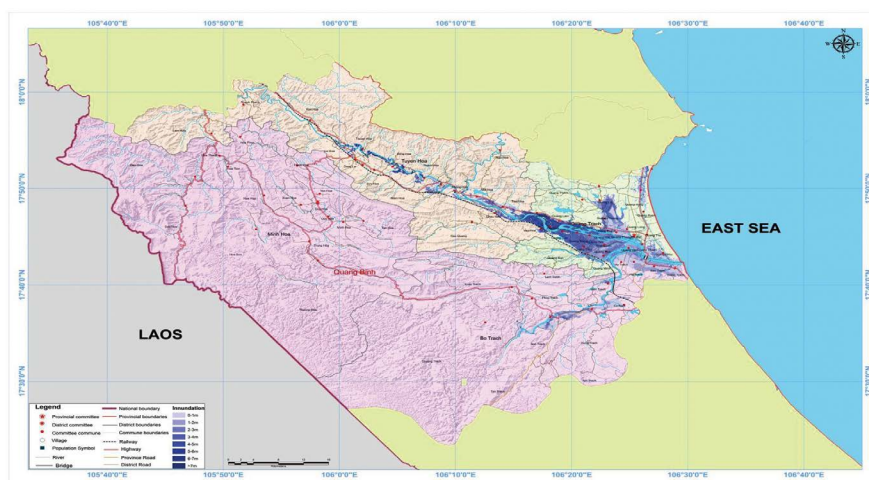
The results of flooding in Gianh river basin corresponding to flood frequency of 5% are presented in Table 4 and Figure 4.

The calculated result of inundation in

the Gianh river basin shows that, with the frequency of 5%, about 164.92 km<sup>2</sup> in Gianh river basin was submerged, of which about 64.38 km<sup>2</sup>, 40.05 km<sup>2</sup>, and 19.78 km<sup>2</sup> were deeply inundated from 0-1 m, 1-2 m, and 2-3 m depth respectively.

**Table 4. The area (km<sup>2</sup>) and percentages (%) of inundation in the districts of Gianh River basin with a frequency of 5%**

No.	District	Inundated depth								
		Total	0-1m	1-2m	2-3m	3-4m	4-5m	5-6m	6-7m	>7m
1	Bo	48.23	31.33	13.57	2.68	0.56	0.09	0.00	0.00	0.00
	Trach	2.27	1.47	0.64	0.13	0.03	0.00	0.00	0.00	0.00
2	Quang	85.31	25.20	20.36	12.98	18.58	5.35	2.20	0.63	0.01
	Trach	13.90	4.10	3.32	2.11	3.03	0.87	0.36	0.10	0.00
3	Tuyen	31.38	7.85	6.13	4.13	4.13	4.84	2.03	0.96	1.31
	Hoa	2.73	0.68	0.53	0.36	0.36	0.42	0.18	0.08	0.11
Total		164.92	64.38	40.05	19.78	23.27	10.28	4.24	1.59	1.32



**Figure 4. Inundation map corresponding to the frequency of 5% on Gianh river basin**

### 3.4. Inundation map corresponding to the frequency of 10%

The calculated results of flooding over Gianh

river basin corresponding to the frequency of 10% are presented in Table 5 and Figure 5.

**Table 5. The area (km<sup>2</sup>) and percentages (%) of inundation in the districts of Gianh River basin with a frequency of 10 %**

No.	District	Inundated depth								
		Total	0-1m	1-2m	2-3m	3-4m	4-5m	5-6m	6-7m	>7m
1	Bo	27.14	14.61	10.84	1.39	0.26	0.03	0.01	0.00	0,00
	Trach	1.28	0.69	0.51	0.07	0.01	0.00	0.00	0.00	0,00
2	Quang	36.39	10.34	10.85	6.07	6.07	2.32	0.71	0.02	0,00
	Trach	5.93	1.68	1.77	0.99	0.99	0.38	0.12	0.00	0,00
3	Tuyen	15.83	6.20	4.59	1.60	1.60	0.78	0.40	0.20	0,47
	Hoa	1.38	0.54	0.40	0.14	0.14	0.07	0.03	0.02	0,04
Total		79.36	31.15	26.28	9.06	7.93	3.13	1.12	0.22	0.47

The calculated results of inundation in Gianh river basin shows that, with the frequency of 10%, about 79.36 km<sup>2</sup> in Gianh river basin was

submerged, of which about 31.15 km<sup>2</sup>, 26.28 km<sup>2</sup>, and 9.06 km<sup>2</sup> were deeply inundated from 0-1 m, 1-2 m, and 2-3 m depth respectively.

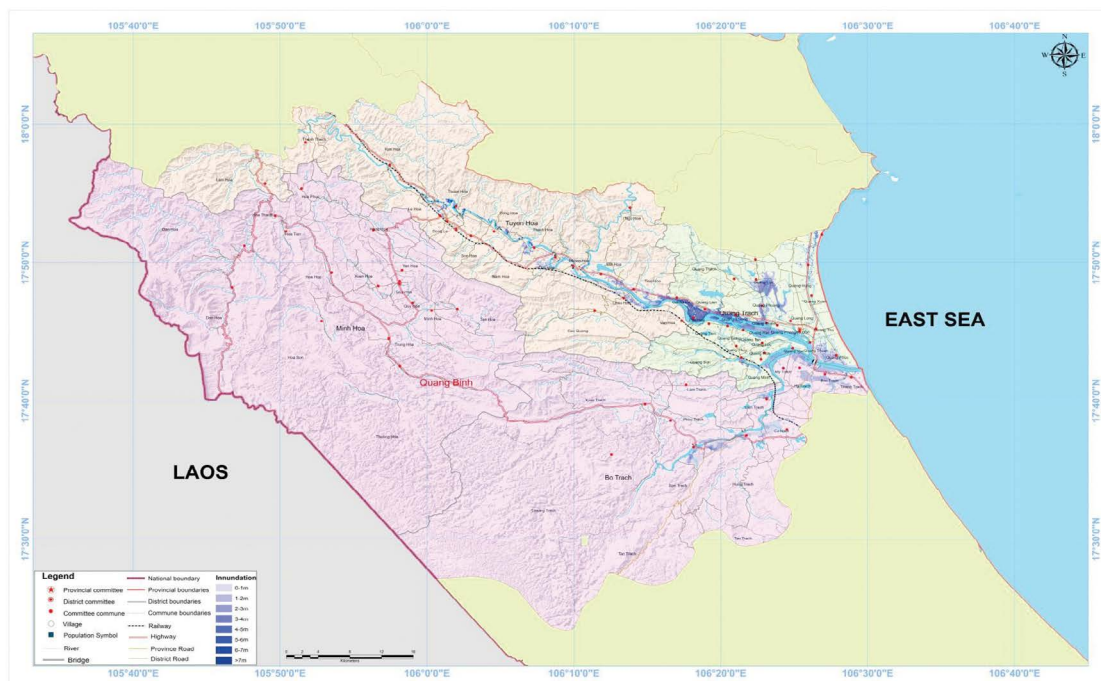


Figure 5. Inundation map corresponding to the frequency of 10% on Gianh River basin

### 3.5. Inundation map corresponding to the frequency of 20%

The calculated results of flooding over Gianh

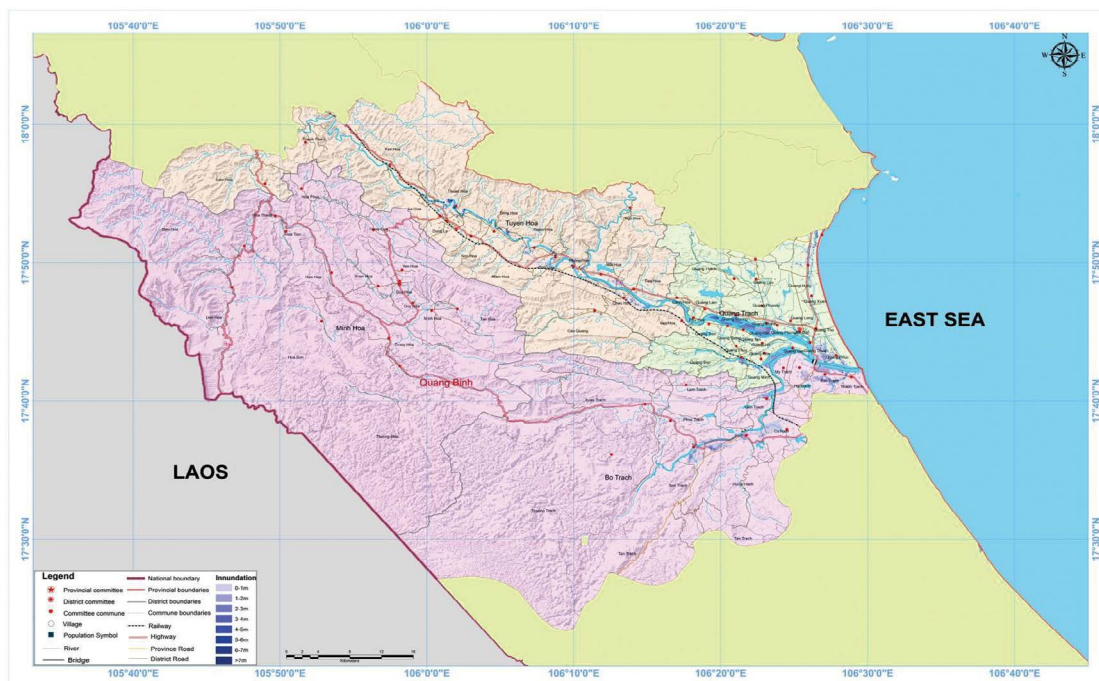
river basin corresponding to the frequency of 20% are presented in Table 6 and Figure 6.

Table 6. The area (km<sup>2</sup>) and percentages (%) of inundation in the districts of Gianh river basin with a frequency of 20 %

No.	District	Inundated depth								
		Total	0-1m	1-2m	2-3m	3-4m	4-5m	5-6m	6-7m	>7m
1	Bo	19.17	12.44	6.15	0.50	0.06	0.01	0.00	0.00	0,00
	Trach	0.90	0.59	0.29	0.02	0.00	0.00	0.00	0.00	0,00
2	Quang	13.11	5.53	5.61	0.89	0.89	0.17	0.02	0.00	0,00
	Trach	2.14	0.90	0.91	0.14	0.14	0.03	0.00	0.00	0,00
3	Tuyen	7.92	4.36	1.78	0.48	0.48	0.26	0.16	0.10	0,29
	Hoa	0.69	0.38	0.15	0.04	0.04	0.02	0.01	0.01	0,03
Total		40.20	22.33	13.55	1.88	1.43	0.44	0.18	0.11	0.29

The calculated results of inundation in the Gianh river basin shows that, with the frequency of 20%, about 40.20 km<sup>2</sup> in Gianh river basin was

submerged, of which about 22.33 km<sup>2</sup>, 13.55 km<sup>2</sup>, and 1.88 km<sup>2</sup> were deeply inundated from 0-1 m, 1-2 m, and 2-3 m depth respectively.



**Figure 6. Inundation map corresponding to the frequency of 20% on Gianh river basin**

### 3.6. Discussion

According to the inundation maps with different frequencies (Figures 2,3,4,5,6), it can be seen that in Gianh River basin, floods occur frequently in both river banks and downstream areas. The Gianh River runs mainly along Tuyen Hoa (in upstream) and Quang Trach (in downstream) districts, so the communes along the river banks of the districts (Thanh Thach, Le Hoa, Mai Hoa, Tien Hoa, Chau Hoa, Thuan Hoa, Canh Hoa, Quang Lien, Quang Tien, Quang Phuong, Quang Phuc for instant) are seriously affected by floods. Moreover, the high proportion of poor people along the river banks of Tuyen Hoa (even the population density is lower than other districts) increases the vulnerability of people as a result of floods.

In Gianh downstream area, especially in the confluence of Gianh and Con rivers, heavy rain and water flows from upstream can stagnate in low terrain and sunken areas with the consequences of flooding's in low elevation, low lying terrain (such as Quang Phuong and

Quang Phuc of Quang Trach district). Fortunately, downstream is usually plain and convenient for economic development (with National Highway 1A runs through and near the sea). This leads to a better infrastructure and a higher living standard and education, consequently in higher ability to withstand floods. It means that although the population density is higher, the vulnerability of the flood is lower compared to a long area of both river banks in Tuyen Hoa district. This area is located in Quang Trach district and coastal area of Bo Trach district.

### 4. Conclusions

In Gianh River basin, flooding frequency is high in both river banks and downstream areas. The Gianh River runs mainly along Tuyen Hoa district in upstream, so the communes along the river banks of the district are seriously affected by floods. Moreover, the high proportion of poor people along the river banks of Tuyen Hoa increases the vulnerability of floods.

At Gianh downstream area, especially in the confluence between Gianh and Con Rivers, when heavy raining occurs, water flows from

upstream will be stagnated at low terrain and sunken area leading to flooded in the low lying terrain areas. However, downstream is usually plain and convenient for economic development, which resulting in a better infrastructure and a higher living standard and education. Consequently, downstream area is in higher ability to withstand floods than in upstream area.

With the frequency of 1%, there is about 229.89 km<sup>2</sup> in Gianh river basin was submerged. Having the higher frequency or shorter return period, the submerged area will be lower. There will be about 180.88 km<sup>2</sup>, 164.92 km<sup>2</sup>, 79.36 km<sup>2</sup>, and 40.20 km<sup>2</sup> in

submerged in Gianh river basin if the frequency is 2%, 5%, 10% and 20% respectively.

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