

# ASSESSMENTS OF VULNERABILITY DUE TO CLIMATE CHANGE IN HA TINH CITY

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**Abstract:** *Climate change is one of the most serious challenges to Ha Tinh City in the coming time, affecting the natural environment, socio-economic development, and especially people's lives. This paper assesses the vulnerability due to climate change in Ha Tinh City by the ADB/NDF/ICEM and UNDP/GEF toolkits through investigating the exposure, sensitivity, and adaptive capacity data of Ha Tinh City. The result shows that most communes and wards have moderate levels of vulnerability, particularly, Dai Nai ward is at a high level and Bac Ha at a low level. In the future, due to the increased risk of climate change, the vulnerability tends to increase, especially at the end of the century. The level of vulnerability of 13/16 wards/communes may increase by 1 or 2 levels, particularly, the Dai Nai, Nguyen Du, Tan Giang and Thach Hung communes/wards would have very high vulnerability. On the contrary, 4 out of 16 communes/wards (accounting for 25%) would be at average level of vulnerability, in which, vulnerability level of the communes (Thach Linh, Tran Phu, Ha Huy Tap) would be unchanged compared to the current situation.*

**Keywords:** *Exposure, sensitivity, adaptive capacity, vulnerability, climate change impacts.*

## 1. Introduction

Ha Tinh is one of the localities affected by natural disasters and climate change. Natural disasters and climate change undermine natural resources, negatively impacting the production system and food security [1, 2, 5]. Within the framework of bilateral cooperation between Viet Nam and Belgium, the provincial project: "Integrated water resources management and urban development related to climate change in Ha Tinh Province" has been implemented to support the Ha Tinh provincial government to increase its ability to adapt to water-related impacts, through strengthening knowledge and capacity development.

To implement this project, SRDP-IWMC Ha Tinh and IMHEN jointly signed a consulting contract named "Assessing vulnerability related to climate change and developing climate change action plan in Ha Tinh City",

with two goals: (i) Support Ha Tinh Province in assessing vulnerability due to climate change impacts on water management and urban development in Ha Tinh City, and (ii) Develop an action plan to respond to climate change for Ha Tinh City.

This paper, based on the research, aims to assess vulnerability due to climate change impacts in Ha Tinh City, including investigate the exposure, sensitivity, and adaptive capacity of Ha Tinh City.

## 2. Data and methodology

### 2.1. Data

#### (1) Data of exposure

The exposure of climate change, based on a set of criteria including 22 factors: Location, distance to the floodplain/riverbank; flood frequency; impacts of floods, droughts, heat wave, and storms; proportion of houses affected by natural disasters; proportion of houses affected by floods; percentage of population affected by natural disasters;

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proportion of population affected by floods; percentage of areas affected by natural disasters; the extent of damage caused by natural disasters; inundated medical, educational, rural, urban, market, agriculture, land; inundated national highway, provincial roads; deep inundated area.

### (2) Data of sensitivity

A set of criteria to assess the sensitivity of climate change consists of four factors: Integrity of design of housing; proportion of children; proportion of the elderly; poverty rate.

### (3) Data of adaptive capacity

Adaptive capacity is assessed based on factors such as: Average income of the household; proportion of people in working age, the rate of swimming, skill, literacy rate; flood awareness; disaster support budget.

The above figures are calculated based on the results of socio-economic surveys. Data for the inundated area were inherited from the project "Technical Consultancy of Hydraulic/Hydrological Model of Rao Cai River Basin and Modelling of Drainage System for Ha Tinh City, related to climate change" [4].

## 2.2. Methodology

The vulnerability assessment is based on the documents of the ADB/NDF/ICEM and UNDP/GEF toolkits, which are widely used by international and domestic organizations in assessing vulnerability.

The vulnerability can be expressed as a function of the level of exposure (E), sensitivity (S) and adaptive capacity (AC) [1,3]. The impact (I) will be the function of the exposure and sensitivity. The general formula is as follows:

$$V = \frac{E \times S}{AC} = \frac{1}{AC} \quad (1)$$

The elements in the formula (1) are defined as follows:

#### *The exposure of climate change (E)*

Exposure is the extent to which a system is exposed to the climate change threat. After identifying the factors, standardising the data for the rational factors, and then decomposing the factors, make the ranking from very low (VL),

low (L), medium (M), high (H), to very high (VH) in accordance with the value of <0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, 0.8-1.0 [1,3].

#### *Sensitivity to climate change (S)*

Sensitivity is the degree to which a system will be affected by, or responsive to the exposure. The potential impact is a function of the level of exposure to climate change threats, and the sensitivity of the target assets or system to that exposure. This includes changes in average climate and frequency as well as extreme weather. Impact may be direct (such as crop change due to temperature changes), or indirect (damage caused by increased coastal flooding frequency) due to sea level rise, and intensity of climate change and the likelihood that the system will be affected by these changes.

After defining the factors, normalizing the data for the quiz factors, and then averaging the factors, performs the rankings from very low (VL), low (L), medium (M), high (H), to very high (VH) in accordance with the value of <0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, ≥0.8 [1,3].

#### *Impacts of climate change (AC)*

Impact assessment is the most important stage in the assessment of vulnerability. Use the impact ranking matrix to rank and carefully record the results in the impact column of the vulnerability matrix. The impact was calculated by the function below:

$$\text{Impact} = \text{Exposure} \times \text{Sensitivity} \quad (2)$$

#### *Adaptability to the threats of climate change*

Adaptive capacity is the adaptation of the natural and human systems to respond to current and future climate impacts, such as reducing damage or utilizing beneficial opportunities.

After the adaptive capacity assessment factors for each commune and ward have been identified, the adaptive capacity and allocation of the competencies will be determined at the different levels from very low (VL), low (L), medium (M), high (H), to very high (VH) in accordance with the value of <0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, 0.8-1.0 [1,5].

Finally, after decentralizing factors of exposure, sensitivity and adaptive capacity, then to score the vulnerability calculation

according to the ranking matrix for each administrative unit in Ha Tinh City [1, 3].

It should be noted that this is a relatively simple ranking method for the purpose of giving a “vulnerability” comparison between communes and wards in the study area. It is based on assumption that current vulnerability is a reliable in predicting vulnerability to future conditions.

### 3. Results and discussion

The following shows the calculation of vulnerability through ratings with criteria for each factor: exposure, sensitivity, impact, adaptive capacity and vulnerability.

#### 3.1. Exposure

The exposure in Ha Tinh City was calculated in Table 1. It can be seen that, the exposures of Tran Phu and Bac Ha currently are very low, despite the increasing of flooded area in the future. Moreover, 4 wards and communes (accounting for 25%) have low exposure, 8 regions have medium exposure. Especially, Dai Nai and Nam Ha have high exposure to climate

change.

At the beginning of 21 century, 7 wards and communes have similar exposure with current state. The exposures of other regions are increased one rank, such as: Bac Ha, Tan Giang, Thach Ha, Thach Mon, Thach Quy, Thach Trung, and Tran Phu.

By mid of century, the exposure is projected increasing one level in Bac Ha, Nguyen Du, Thach Ha, and Thach Mon. The regions with high exposure increase from 2 (at the current) to 8 (at the middle) as: Dai Nai, Nam Ha, Nguyen Du, Tan Giang, Thach Binh, Thach Ha, Thach Hung, Thach Mon.

By the end of 21 century, the exposure is significantly increased. It increases one rank in 13 ward and communes. The exposures of Thach Binh, Thach Ha, Thach Mon are similar to the middle of century. The exposures of Dai Nai, Nam Ha, Nguyen Du, Tan Giang, Thach Hung are increased to the rank of very high (VH) by the end of century.

Thus, comparing with current, the exposure in Ha Tinh City is significantly increased in the future.

*Table 1. Table of hierarchy of exposure levels corresponding to the periods [1,2]*

Administrative units	Current	2016-2035	2046-2065	2080-2099
Bac Ha	VL	VL	L	M
Dai Nai	H	H	H	VH
Ha Huy Tap	M	M	M	H
Nam Ha	H	H	H	VH
Nguyen Du	M	M	H	VH
Tan Giang	M	H	H	VH
Thach Binh	M	M	H	H
Thach Dong	M	M	M	H
Thach Ha	L	M	H	H
Thach Hang	M	H	H	VH
Thach Linh	M	M	M	H
Thach Mon	L	M	H	H
Thach Quy	L	M	M	H
Thach Trung	L	M	M	H
Tran Phu	VL	L	L	M
Van Yen	M	M	M	H

### 3.2 Sensitivity

The current sensitivity was calculated and mapped in Figure 1. The high sensitivity is seen in Ha Huy Tap, Thach Binh, Thach Dong, Thach Quy, Thach Mon because of the high rate of four-level houses, the old, children and the poor in these regions. The sensitivity of Bac Ha, Nam Ha, Tran Phu is low; these wards have low

sensitivity because of urban area, invested strongly in infrastructure, so the ability to withstand the risks of climate change in the future. Seven wards and communes (accounting for 43,75%) have medium sensitivity. Since there is no future sensitivity data, in this study, we use the current sensitivity data, combined with other factors to calculate vulnerability levels.

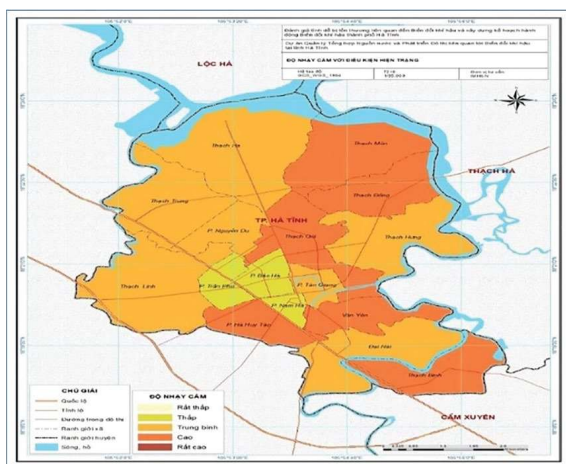


Figure 1. Sensitivity map for Ha Tinh City [1]

### 3.3. Impacts

The ranking of exposure and sensitivity were combined to determine impact in accordance with the impact scoring matrix. Table 2 shows impact ranking for Ha Tinh City.

Under the current climate conditions, the impacts of climate change on most of wards and communes in Ha Tinh City are at medium level (M). The impact on Tran Phu and Bac Ha are low due to the low sensitivity and low exposure. The high exposure and sensitivity of Dai Nai cause high impact.

In the early part of the 21<sup>st</sup> century (2016-2035), the impact of climate change is projected to increase one rank, such as in Thach Hung and Tan Giang. The impacts of other regions are similar to current.

At the middle of century, the impacts of 4 wards and communes (Thach Mon, Thach Ha, Thach Binh, Nguyen Du) increase one rank from medium to high compared with the beginning of century.

By the end of 21<sup>st</sup> century, the impact of climate change is significantly increased due to the increasing of exposure with on rank higher

in most of wards and communes.

### 3.4. Adaptive capacity

The adaptive capacity for Ha Tinh City was calculated and mapped in Figure 2. Similar to sensitivity, the adaptive capacity in the future is assumed to be similar as that in the current situation. This may not be strictly correct as continued economic development in the region is likely to change many factors that will give rise to changes in adaptive capacity. There is however no way to predict how this adaptive capacity may change. For example, on the one hand the impact of climate change may restrict development in a location while on the other hand economic improvement related to external factors may improve living conditions and therefore improve adaptive capacity.

The adaptive capacity of Bac Ha, Ha Huy Tap and Thach Linh are high due to the high income (more than 38 million per year) and high awareness of climate change impact. Whereas, the adaptive capacity of Dai Nai, Thach Mon, Thach Dong, Thach Quy, Van Yen are low due to the low rate of swimming skills (under 40%), low income, and low awareness of climate change.

Table 2. Impact ranking based on exposure and sensitivity level [1]

Administrative units	Current	2016-2035	2046-2065	2080-2099
Bac Ha	L	L	L	M
Dai Nai	H	H	H	VH
Ha Huy Tap	M	M	M	H
Nam Ha	M	M	M	H
Nguyen Du	M	M	H	VH
Tan Giang	M	H	H	VH
Thach Binh	M	M	H	H
Thach Dong	M	M	M	H
Thach Ha	M	M	H	H
Thach Hang	M	H	H	VH
Thach Linh	M	M	M	H
Thach Mon	M	M	H	H
Thach Quy	M	M	M	H
Thach Trung	M	M	M	H
Tran Phu	L	L	L	M
Van Yen	M	M	M	H

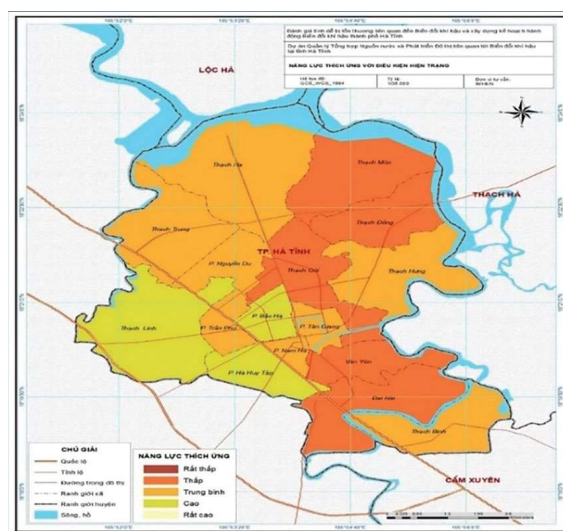


Figure 2. Adaptive capacity map of Ha Tinh City [1]

### 3.5. Vulnerability assessment

The final vulnerability score is determined by considering the impact and adaptation capacity together. To do so, we the impact and adaptive capacity of each of threat and plot them on the vulnerability scoring matrix.

An important point is that with increasing severity of impact, vulnerability of the target infrastructure system increases.

Adaptation capacity has the opposite effect: with increasing adaptive capacity an infrastructure system would have reduced vulnerability.

In the future, the vulnerability of wards and communes in Ha Tinh City is projected to increase, especially by the end of 21 century (Figure 3).

*Bac Ha ward:* This ward is located in the



centre of the city with the smallest natural land surface area (1.71% of the total). However, the population of this ward is highest, 11.62%. The vulnerability of Bac Ha is low due to the low exposure and high adaptive capacity. By the end of 21 century, human life and business in Bac Ha are seriously affected by climate change, and caused medium vulnerability.

*Dai Nai ward:* The vulnerability is high due to many reasons as nearing Rao Cai river, low topography, high influence of flood, high rate of the old (30%) and poor (4%), low rate of swimmer (30%). In the future, the impact of climate change increases, especially the influence of flood (100% land use types are flooded) caused the increasing of vulnerability.

*Nam Ha ward:* The vulnerability is medium due to the high rate of solid house and high income (50 million/year). By the end of 21 century, the vulnerability increases from medium to high because of the increasing of exposure and the decreasing of adaptive capacity.

*Nguyen Du ward:* Similar to Nam Ha, the vulnerability in Nguyen Du ward is medium at the current. In the future, the vulnerability increases significantly, can reach to high rank at the middle and very high rank at the end of 21 century. The increasing of vulnerability due to the increasing of flooded area, medium adaptive capacity and low budget for natural disasters prevention (30 million/year).

*Tan Giang ward:* This ward has high exposure to climate change, it can reach to very high rank by the end of century. The vulnerability is very high due to the medium adaptive capacity, low awareness of climate change, low budget for natural disasters prevention (20 million/year).

*Thach Binh commune:* The vulnerability of Thach Binh is medium at the current and the beginning of century. At the middle and the end, the vulnerability is high because of the increasing influence of flood, low income (31.2 million/year), high rate of the old (15%) and children (30%).

*Thach Dong commune:* The vulnerability of Thach Dong is medium at the current, the beginning and the middle of century. By the end

of 21 century, the vulnerability of this region is projected to be high.

*Thach Ha commune:* At current and the beginning of century, the vulnerability of this region is medium. At the middle and the end of century, the vulnerability is high due to the location next to Ke Go lake, the increasing of flooded area, low adaptive capacity and low income (30 million/year).

*Thach Hung commune:* At current, the vulnerability is medium. In the future, the vulnerability of this commune increases; at the beginning and middle of century, the vulnerability is high; by the end of 21 century, the vulnerability is very high due to the location next to river, low budget for natural disasters prevention (10 million per year), serious influence of flood on agriculture, health, transport, education.

*Thach Linh commune:* The vulnerability of this commune is medium and not changes much in the future because of low influence of flood and high adaptive capacity.

*Thach Mon commune:* This commune has the highest rate of four-level house (50%), high exposure to flood, low budget for natural disasters prevention (17 million per year), low income (31.88 million per year). The vulnerability increases in the future; it will be high at the middle and the end of 21 century.

*Thach Quy commune:* This commune has high sensitivity due to the high rate of four-level house (50%), low adaptive capacity caused medium vulnerability at the middle of century. By the end of 21 century, the vulnerability is high due to the seriously influence of flood on business.

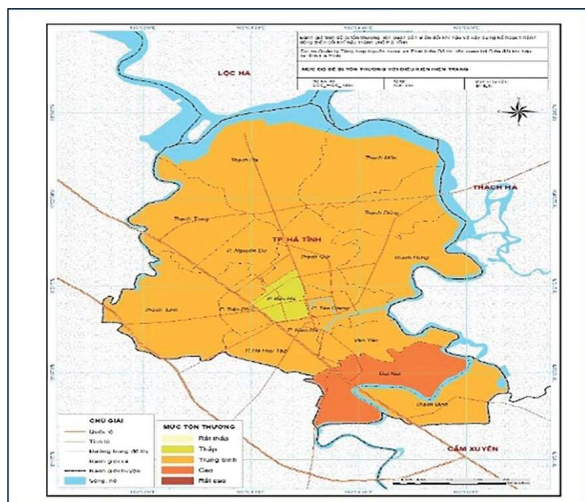
*Thach Trung commune:* In the future, the vulnerability of Thach Trung is high by the end of century, because of the increasing impact of climate change on economic structure, livelihood and infrastructure.

*Tran Phu ward:* Although the exposure of this ward increases in the future, the vulnerability of Tran Phu is medium and likely similar in the future due to the large annual budget for natural disasters prevention (100 million per year), high resilient infrastructure.

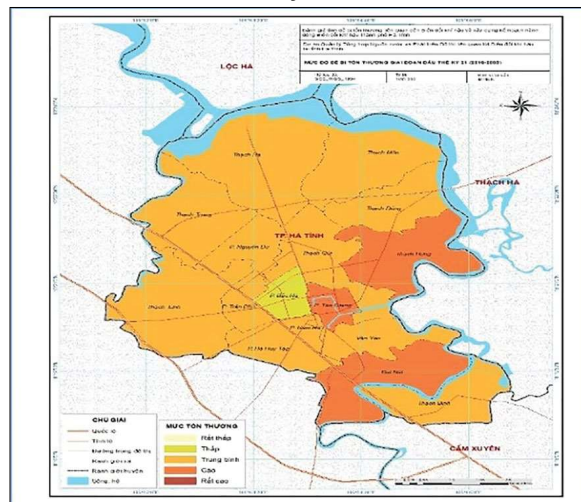
*Van Yen ward*: The vulnerability of this ward increases in the future; by the end of century, the vulnerability is high. This ward is vulnerable

to flood due to the location next to Rao Cai river, low income (25 million per year), the low rate of swimmer (20%) and low adaptive capacity.

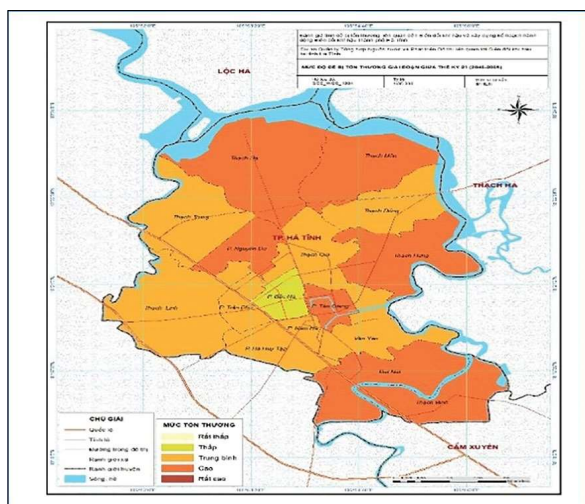
*Current*



*Period of 2016-2035*



*Period of 2046-2065*



*Period of 2080-2099*

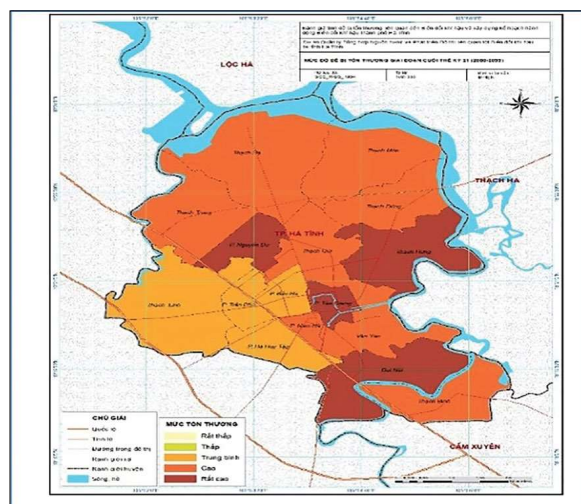


Figure 3. Vulnerability map for Ha Tinh City [1]

#### 4. Conclusions

Ha Tinh is one of the localities affected by natural disasters and climate change which causes natural resources undermined, negatively impacting the production system, food security, people's lives and other vulnerable objects. For assessing vulnerability to climate change in Ha Tinh City according to ADB/NDF method, a set of evaluation criteria includes 3 components: exposure, sensitivity, adaptive capacity was developed and analysed.

At present status, most communes and wards have medium levels of vulnerability, particularly Dai Nai ward at a high level and Bac Ha at a low level. In the future, due to the risk increase of climate change, the vulnerability tends to increase especially at the end of the century. There are 13/16 wards, commune vulnerability increases by 1 or 2 levels. Particularly, communes and wards such as Dai Nai, Nguyen Du, Tan Giang and Thach Hung have a very high vulnerability, consistent with the assessment of the initial increase in

exposure. In contrast, 4/16 communes, wards are at a medium level of vulnerability, in

which 3 communes do not change compared to the current level.

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