

# Climate change impacts and adaptation measures for Quy Nhon city

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**Abstract.** In the framework of the program "Asian Cities Climate Change Resilience Network" funded by Rockefeller Foundation, Vietnam Institute of Hydrology, Meteorology and Environment carried out this study with the aim to strongly support the development of action plan to respond to climate change for Quy Nhon city. The study developed climate change (temperature and rainfall) and sea level rise scenarios corresponding to some key emission scenarios, namely A1FI, A2 and B2. Impacts of climate change on main sectors such as water resources, agriculture and tourism were also assessed. These were used as the basis for proposing adaptation measures.

*Keywords:* climate change, adaptation measures, Quy Nhon.

## 1. Introduction

Assessment of climate change impacts on factors of nature and socio-economics together with the development of adaptation strategy and mitigation of climate change are of high concerns in many countries all over the world. The Intergovernmental Panel on Climate Change and many nations has developed and updated climate change scenarios so that potential impacts could be identified. Based on those impacts, adaptation measures to respond to climate change on global and national scales have been proposed. Within "Asian Cities Climate Change Resilience Network" program,

Quy Nhon is one of three representative cities of Vietnam that was chosen for the development of action plan to respond to climate change due to its important role on socio-economic development of Central key economic region. The city is projected to be heavily affected by climate change, especially flood, storm and anomalous weather events. The main impacted area is the zone concentrated by low income people living in cultivated area, farmers and fishermen, leading to many socio-economic issues. Thus, assessment of climate change and sea level rise impacts as well as proposal of corresponding response measures are of very importance in the strategy development for the city.

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## 2. Climate change, sea level rise scenarios and their impacts

### 2.1. Climate change and sea level rise scenarios

Climate change and sea level rise scenarios in Quy Nhon were developed by the Vietnam Institute of Hydrology, Meteorology and Environment (IMHEN) with several emission scenarios (from low to high). MAGICC/SCENGEN 5.3 software and statistical downscaling method were selected for the development of climate change and sea level rise scenarios in the 21<sup>st</sup> century [1]. Temperature and rainfall scenarios were set up on monthly and seasonally basis in the year of 2020, 2030, 2040 and 2050 corresponding to highest emission scenario of the high scenario group (A1FI), intermediate emission scenario of the high scenario group (A2) and intermediate emission scenario of the medium scenario group (B2).

Due to the complexity of climate change and limited understanding of climate change, both in Vietnam and in the world, together with many other factors, namely the psychological, social, economic factors, uncertainties of greenhouse gas emissions scenarios, uncertainties of model-estimated results etc., the most harmonious scenarios is the medium scenario (B2) which is recommended for many ministries, sectors and provinces/cities to use as an initial basis in climate change and sea level rise impact assessments and in the development of action plans to respond to climate change [2].

#### 2.1.1. Climate change scenarios

##### a) Temperature

The results of the study show that monthly mean temperature would increase by 0.3°C in 2020 to 1.5°C in 2050. Monthly mean of temperature from May to August are projected

to be higher than 30°C. Specifically, up to 2050, the mean temperature in these months would be around 31°C, increasing by 0.6 to 1.1°C. April is projected to be the hottest month in the year, increasing by 0.7°C in 2020 to 1.5°C in 2050 (Figure 1).

##### b) Rainfall

Projected results show that rainfall increases in rainy season and decreases in dry season. Up to 2050, rainfall decreases in dry season about 14.5 mm (0.74%) and increases in rainy season up to 82.2 mm (4.21%). Intensive increase in rainfall is from September to December and decrease is from March to May. Up to 2050, rainfall reaches to the highest in October at 633mm and the lowest in March at 23 mm. Nevertheless, annual mean rainfall is increasing; the total reaches to 1955.9 mm in 2050.

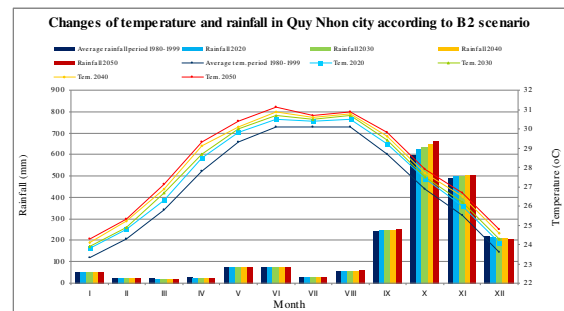


Figure 1. Changes of temperature and rainfall in Quy Nhon city according to B2 scenario.

##### c) Projected changes of the storm due to climate change

Recent studies show that when sea level rises, hurricane hits the mainland more quickly, causing heavy rain and flood. In recent decades, storms have the trend to move southward and occur later in the year. According to IPCC, the occurrence of the storm would change as climate change [3]; therefore, there would be more storms with more frequency, higher intensity and longer storm season.

ENSO phenomenon affects global weather, climate at different levels. Quy Nhon is located in the Central region which will be the most vulnerable region to climate change if ENSO occurs. This impact expresses in standard error of rainfall and temperature stability in each ENSO period.

Monitoring data at Quy Nhon Hydrological - Meteorological station shows that cyclical impact of warm-phase ENSO (EL Nino) tends to increase during the last decades of 20<sup>th</sup> and early 21<sup>st</sup> century (average 2 to 4 years) in comparison with itself of the first half of 20<sup>th</sup> century. Maximum temperature of several months in the summer of 1986, 1987, 1992, 1998, 2003, 2005 and 2007 was 1-1.5°C higher than the monthly mean and 3.2-4.7°C higher than the annual mean as compared to the previous years. Rainfall in Quy Nhon area is strongly fluctuating. Compared with the average rainfall of multi years, rainfall tended to increase in the period of 1955-1964, then markedly decreased in 1965-1984 and increase again during the period of 1985-2004. In addition, rainstorm and flood in Binh Dinh normally occurs in late October, but in recent years, due to the anomalous variation of rainfall, floods came very early in 2000 and 2005 or came very late in 2001; sea level and flood peak were often higher than before [4].

### 2.1.2. Sea level rise

According to the medium emission scenario (B2), sea level is expected to rise about 12, 17, 23 and 30 cm in 2020, 2030, 2040 and 2050 respectively, compared to that of the period 1980 – 1999. Inundation area due to sea level rise will increase by 1.4 to 1.47 km<sup>2</sup> (cover 0.7-0.8% of total area of the city). Inundation effected land is on low-lying area of Nhon Ly and Nhon Hoi communes.

## 2.2. Impacts of climate change

### 2.2.1. Impacts of climate change on water resources

The impacts of climate change on water resources in Quy Nhon were assessed for the Kone-Ha Thanh river basin in 2010, 2020 and 2050 using three different models namely, HEC-HMS, MIKE BASIN and MIKE 11 based on the baseline scenario in 2007. The research focused on several hydrological characteristics, namely water balance (including inflow and water demand), water quality (Dissolved Oxygen – DO, Biological Oxygen Demand - BOD, Chemical Oxygen Demand – COD) and salinity intrusion.

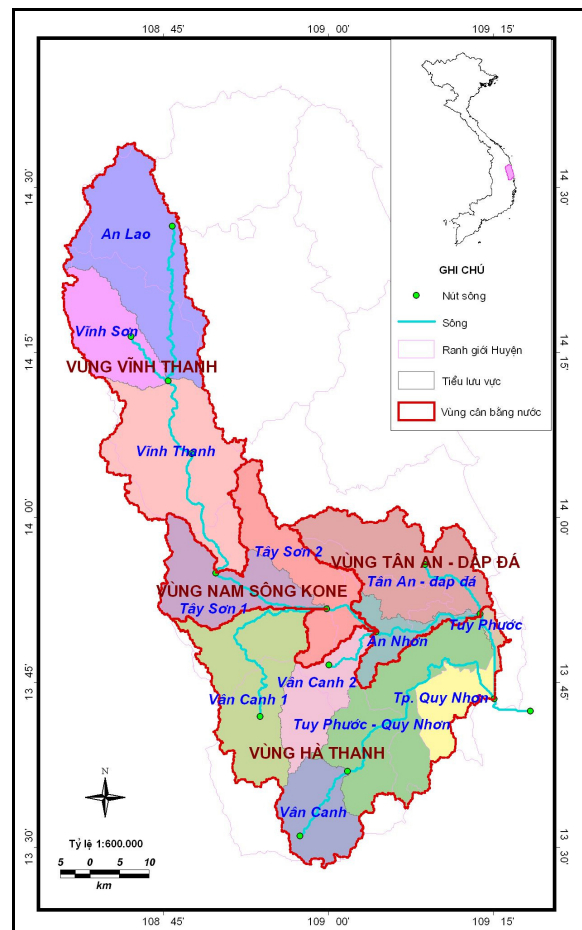


Figure 2. Kone-Ha Thanh sub-basins for water balance calculation by using MIKE BASIN.

### a) Water balance

For the baseline (2007), results of the water balance evaluation shows that Quy Nhon lacks 0.683 million m<sup>3</sup> water, equivalent to 12.2% of the water shortage in Kone-Ha Thanh basin which is 5.620 million m<sup>3</sup>.

Up to 2020: water shortage of the city would reach to the serious level, approximately 2.680 million m<sup>3</sup>, around four times as compared to 2007 and equaling to about 7.6% of water shortage of entire basin.

Up to 2050: For the scenario 1 that population grows rapidly and reaches its peak

in 2050 (at the rate of 1.7%) together with the scatter in the application of technology and measures in industry and agriculture (reduction of coefficient of irrigation), water shortage is about 11.8 million m<sup>3</sup>. Meanwhile, in the case of scenario 2 that population growth is at average rate (1.5%) and advanced technologies are applied in agriculture (increase of coefficient of irrigation), water shortage decreases to 10.6 million m<sup>3</sup>, around 4 times higher as compared to 2020 (Table 1).

Table 1. Water shortage in Kone-Ha Thanh river basin.

No.	Sub-basins	Year					Unit: 10 <sup>6</sup> m <sup>3</sup>	
		2007	2010	2020	2050			
					Scenario 1	Scenario 2		
1	Quy Nhon city	0.683	1.768	2.680	11.803	10.599		
2	Tuy Phuoc	0.094	0.243	0.368	1.622	1.456		
3	Tuy Phuoc – Quy Nhon	1.857	4.808	7.289	32.101	28.826		
4	Van Canh	0.062	0.160	0.242	1.067	0.958		
5	Van Canh 1	0.130	0.337	0.510	2.248	2.019		
6	Van Canh 2	0.063	0.163	0.247	1.086	0.975		
7	Tay Son 1	0.045	1.128	2.413	2.782	2.034		
8	Tay Son 2	0.045	1.129	2.417	2.787	2.037		
9	An Nhon	0.539	2.376	3.894	4.347	3.404		
10	Tan An – Đập Đa	2.102	9.265	15.181	16.950	13.271		
11	An Lao	0.000	0.000	0.008	0.035	0.002		
12	Vinh Son	0.000	0.000	0.003	0.015	0.001		
13	Vinh Thanh	0.000	0.000	0.008	0.035	0.002		

### b) Water quality

In Binh Dinh province, industrial parks and clusters (IPs and ICs) locate in main sites of the river basin where population concentrate the most. They are one of the reasons causing the pollution of the rivers. Currently, the concentration of DO in the river around the large industrial parks is about 2,01 – 3,5 mg/l, while concentrations of BOD and COD at several locations do not meet the Vietnam

standard for surface water quality type B with the maximum of 40mg/l and 74mg/l, respectively.

Up to 2020 and 2050, surface water quality of downstream Kone-Ha Thanh in general and of Quy Nhon in particular is projected based on the following scenarios:

Scenario 1: No treatment of waste water in industrial parks and clusters and sea level rise impacts are taken into account. Up to 2020, the

concentration of DO in the river continuously declines partly due to the impact of salinity which decrease dissolved oxygen in water. In addition, industrialization discharging large amount of pollutants into the rivers leads to the reduction in concentration of DO and the increase of BOD and COD. Specially, concentration of DO reaches to the minimum of about 2.0mg/l, concentration of BOD increases by 2.0mg/l and concentration of COD increases by 7.0 mg/l. Up to 2050, if sea level rise by 33 cm, concentration of BOD increases by 1-2 mg/l, COD increases by 2-3 mg/l as compared to those in 2020.

Scenario 2: Waste treatment meets Vietnam standard for surface water quality type B and sea level rise impacts are taken into account. Up to 2020, surface water quality in Quy Nhon is projected to have positive changes. Average concentration of BOD is 17.4-30.0 mg/l and reaches the maximum of 40 mg/l; average content of COD is 14.2 mg/l and reaches the maximum of 78.2 mg/l. In 2050, concentration of DO is 3.6-5.2 mg/l, concentration of BOD decreases to 16.3-39 mg/l, and concentration of COD is 13.1-78 mg/l.

#### *c) Salinity intrusion*

In Binh Dinh province, the most affected areas are Quy Nhon city, Tuy Phuoc district and a part of An Nhon district. By 2020, saline water intrudes up to a distance of 200-300 meters in the main rivers having the salinity of 2 PSU. The required time to reach the salinity level of current scenario is almost similar equaling to about 2-3 days. Saline water intrudes further into inland in 2050 as compared to 2020. Nhon Binh and Nhon Phu are the most effected areas by salinisation with the maximum of 13.3 PSU which are 2.4 and 3.0 PSU more than that of current and in 2020, respectively.

### *2.2.2. Rapid assessment of climate change impacts on some economic sectors [5]*

#### *a) Agriculture*

Most of the damage is caused by the impacts of climate change on agricultural production. The main types of disaster in Quy Nhon include:

- Flood: Flooding may result from heavy rainfall or sea level rise. Flood can cause loss or less harvest productivity. In the future, effects of flood can be worse due to climate change, flood cycle would change with the increase in frequency and intensity.

- Drought: In dry season, low rainfall, frequently western wind, and long period of heat, together with poor water storage capacity in short and steep rivers causes water shortage in agricultural production and salinization. The most vulnerable areas are listed above. Salinization occurs in Con and Ha Thanh estuaries of Nhon Binh, Nhon Phu wards and Nhon Hoi commune. Besides, long period of drought affects livestock and poultry in the region as risk of disease outbreak in the hot season.

#### *b) Aquaculture*

Aquaculture area in Quy Nhon is mainly for shrimp farming (250 hectares). In the updated development plan of aquaculture in Binh Dinh to 2020, the entire irrigation system for aquaculture will be upgraded; the total aquaculture area will be 527 ha. However, the climate change factors have not been considered. Rainfall and temperature are the two main climatic factors affecting aquaculture. Fishermen often cultivate for 9 months during the dry season. Recently, an anomalous heavy rain during the dry season has caused significant damage to the fishery sector. One of the reasons is that large influx of freshwater

reduces the pH level in the ponds and leads to a decrease in aquaculture production.

In the rainy season, there is no activity of fishery so that the productivity is not affected. However, when floods occurring with greater intensity will damage fishery infrastructure. In addition, extreme temperature in a long time has great influence on fishery. The proper temperatures for normal growth of shrimp is 27-30°C, while the temperature > 35°C or < 20°C for 2-3 days, shrimp will die.

#### *c) Fishing*

According to the plan in 2020, a number of projects will be implemented, for example: building system of warning, forecasting, rescuing; expanding Quy Nhon fishing port, Quy Nhon storm shelter; upgrade fishing ship and service, infrastructure and other techniques. In the future, in term of climate change impact, the hurricane will probably occur more frequently. So, if the habit is unchanged (the fishermen do not use the communication devices while go fishing offshore), the anchorage area does not guarantee the size and safety, rudimentary and small boats still used for offshore fishing will be in risk of heavy damage and fishermen are the most impacted and most vulnerable.

#### *d) Tourism*

The development plan of Binh Dinh to 2020 has given the priority to the investment to marine tourism. Besides, the infrastructures for tourism such as hotels, restaurants, services, sports area resorts will be built along the coast. According to climate change scenarios, coastal areas of Vietnam in general and Binh Dinh, Quy Nhon in particular will be affected by sea level rise, storm surges, floods and heat increase triggering soil erosion, coastal flooding, environmental pollution, outbreak of epidemics, etc.. All the above factors will affect

tourism (beach/tourist areas, the depletion of tourism resources, reducing the amount of tourists). However, in the tourism development plan has not considered the response to risks of natural disasters, extreme weather. Tourism department does not have even a representative in the Committee for the Prevention of Flood and Rescue of Binh Dinh province on order to receive and exchange updated information on natural disasters, participate in formulating prevention plans to reduce natural disaster or coordinating closely with other agencies to respond effectively when disasters occur. This is one of the restrictions that should be considered thoroughly in the process of completing tourism development plan.

### **3. Adaptation measures to respond to climate change in Quy Nhon**

For agriculture, aquaculture and forestry: most of manufacturing operations are dependent on the weather. Moreover, poor people group mainly work in these sectors, their production are made just to maintain their lives and there is almost no accumulation, which leads to the fact that they cannot afford equipping themselves with better conditions to respond to natural disasters, such as : strong houses, equipment, facilities and production capital. Addition, the perception is poor, backward practices; the community is not high increases vulnerability to natural disasters. To overcome these problems, some relevant activities need to be performed, including: (i) raising awareness of people about climate change and other threats, (ii) planning to develop manufacture based on the climate change research to integrate into the operations, (iii) policies to support (such as funds, facilities and equipment), insurance and resettlement in line with community participation, and (iv)

community education enhancement. Nevertheless, the most important activity when the city is expanded and developed is supporting these groups to gain new vocational skills to change their livelihoods to get a better and more sustainable life.

Tourism: the proportion of revenue from tourism in Quy Nhon will be very high in the future. Most of tourism infrastructure is located near the sea, which is greatly influenced by natural disasters and coastal erosion. Many resorts have been planned according to research; they will be affected by rising sea levels, together with phenomena of strong coastal erosion. Thus, there should be extensive research on shoreline stabilization under the impact of sea level rise to re-plan seaside resort, and should have the support and insurance policy for the sector.

The city now has got the organizational structure and facilities to prevent and reduce natural disasters as well as search and secure. However, they have not met the current needs. In the future, when the disasters caused by climate change occur with greater intensity, higher frequency, Quy Nhon City should: invest in construction of warning and forecasting systems, information systems and response and rescue device; train and improve the capacity and awareness about climate change and its impacts in order to make appropriate adaptation measures for not only professional staffs but for all government organizations, unions and each citizen; enhance the participation of the people, especially women in activities of planning, resettlement, making plans and producing appropriate measures, to cope with the impacts of natural disasters and climate change; strengthen specialized research activities to find solutions for planning and making plans to adapt to climate change conditions.

A number of activities which are important to make plan of climate change adaptation in Quy Nhon in the near future have been proposed, including intensive research for the eastern districts of Tuy Phuoc commune on the susceptibility to climate change and guidelines for making plans to develop urban areas, construction, infrastructure and agriculture; building instructions, new procedures for the resettlement, support for changing livelihood of fishing households vulnerable to climate change; Improve the capacity, organization and equipment for Flood and Storm Control Committee and the Search and Rescue; program of raising awareness, instructions, warning signs for communities susceptible to flooding; Invest to research design, repair and upgrade the system of river and sea dykes, to not only strengthen but also ensure safety in extreme conditions in the future.

#### 4. Conclusions

1) Climate change and sea level rise scenarios were developed for Quy Nhon city using emission scenarios A1FI, A2 and B2. By mid 21<sup>st</sup> century: i) monthly and seasonal mean of the temperature in Quy Nhon city would increase compared to that of the period 1980-1999; ii) rainfall would increase in rainy season and decrease in dry season, but in term of annual mean, rainfall would be still increase; iii) sea level is expected to increase about 30cm compared to the period of 1980 – 1999.

2) In Quy Nhon, water resources, agriculture and tourism are considered as major sectors would be affected by climate change.

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