MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT

Institute of Meteorological, Hydrological and Environment

MINISTRY OF FOREIGN AFFAIRS OF THE NETHERLANDS

The Netherlands Climate Assistance Program

PROJECT

Climate Change Impacts in Huong River Basin and Adaptation in its Coastal District Phu Vang, Thua Thien Hue province

FINAL REPORT

Ha Noi, April 2008

CONTENT

ABBREVIATIONS

ADB	Asian Development Bank
CC	Climate Change
C	Carbon
cm	Centimeter
CO_2	Carbon dioxide
ĐDSH	biodiversity
EIA	Environment impact assessment
ERU	Emission Reduction Unit
EU	European Union
ETC	?
EVN	Vietnam Electricity Corporation
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
IWRM	Integrated Water Resources Management
HMS	Hydro-meteorology Service
MARD	Ministry of Agriculture and Rural Development (Vietnam)
MOI	Ministry of Industry
MONRE	Ministry of Natural Resources and Environment
mm	Millimeter
m^3	Cubic meter
m^2	Square meter
m/s	Meter/second
Mo	Module of annual runoff
NCAP	Netherlands Climate Assistance Program
TFPSR	Typhoon and Flood Prevention, Search and Rescue
ppb	Portion per billion
ppm	Portion per million
ICZM	Integrated Coastal Zone Management
Q	Water discharge
TTH	Thua Thien Hue
PPC	Provincial People's Committee
IMHEN	Institute of Meteorological, Hydrological and Environmental

W	Total annual runoff
TCES	Tropical Cyclone in the East Sea
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
Y	Depth of flow

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27. Results of research of project NCAP on climate change and potential CC impacts on Thua Thien Hue, Project management Unit and technical experts of IHMEN Technical experts of Thua Thien Hue, Department of Natural Resources and Environment, (Vietnamese)

28. Livelihood, vulnerability and local adaptation strategies to natural disasters in Huong river basin, Case study in Thuan An town, Phu Vang district Thua Thien Hue province, Hue Centre for Social Sciences and Humanities – Hue science university**.**

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INTRODUCTION

(1) Project "Climate Change Impacts in Huong River Basin and Adaptation in its Coastal District Phu Vang, Thua Thien Hue province"

Is one of components in the Netherlands Climate Assistance Program (NCAP), formerly the Netherlands Climate Change Studies and Assistance Program, phase 2 (NCAP2), which had been implemented in 14 developing countries on the world. This is a pilot research on climate change impacts on natural environment, water resources, socio-economic development and the most vulnerable population communities; at the same time it is a pilot case study on recommendation and carrying out the policy and measures to adapt to climate change.

The project regards the Huong River Basin in Thua Thien Hue Province in general and its lagoon population in particular. Future impacts of climate change on the water system and flows of the entire river basin will be projected in an integrated way. The social-economic focus is on the coastal district of Phu Vang in order to involve vulnerable stakeholders in preparing measures to adapt to the projected climate change impacts in their local area.

(2) The project has the following objectives:

Development objectives:

The development objective of the project is to strengthen the capacity of the sectors, institutions and people in province to adapt and respond to the climate change impacts in order to reduce their vulnerability to climate change and disasters by raising their understanding and preparedness, to foresee, minimize the negative impacts and losses.

Through this, the project may also contribute to the implementation of Vietnam national strategy on poverty elimination and sustainable development. The results and findings of the project may be analyzed to develop a participatory climate change adaptation and integrated water resources model, which can be used in other basins and areas nation-wide.

Project objectives:

To study existing and future climate change impacts on water resources in Huong river basin and understand how people's livelihoods strongly depend on climate and water resource changes.

To improve awareness, a pro-active attitude and preparedness regarding climate change and its impacts among all related stakeholders,

To assess, prioritize and improve the existing adaptation measures with stakeholders' participation.

To prepare and develop, with stakeholders participation, the adaptation plan and policy at district and provincial levels.

Research, develop and propose the programs, measures and policies of feasible adaptation in localities; replicate and apply for other provinces and regions.

(3) The project has applied successfully the model methods of research in combination with traditional ones and with stakeholder participation approaches:

Combine the use of research method, mathematical model and participatory tools:

The project combines the stakeholder approach with water modeling. The technical scientific tools were selected and employed on the basis of needs as by IMHEN and will support local awareness raising and designing of adaptation measures.

Participatory tools facilitated the presentation and discussion of water modeling results in the province as well the follow-up that will aim at demand driven needs and timely adaptation to the benefit of the most vulnerable people.

The process of exchange and discussion on the research results at localities can determine the true requirements and adaptation measures which bring about benefits for the most vulnerable objects.

Collect and inherit the results of other projects which had been carried out in area, including impact assessment, assessment of participatory capability of stakeholder and the level of implementing adaptation measures.

(4) From starting to ending, the project focuses on the following activity group:

a) Collect data on natural and social conditions of Thua Thien Hue Province, the Huong River basin and Phu Vang District, case study of project.

b) Analyze and evaluate the evolution of climate and hydrological elements, especially natural disasters in Thua Thien Hue during the last half century.

c) Research and develop scenarios of the main climate and hydrological elements: temperature, rainfall, potential evaporation, runoff, sea level rise, depth of flood, flooded area, salinity and salinity intrusion of Thua Thien Hue Province, depth of flood and flooded area of Phu Vang District in the coming decades.

d) Assess the impacts of climate change on the increasing of intensiveness and frequencies of climate and hydrological elements, particularly the extreme ones, the degeneration of environmental and ecological components and their negative effects on economic and social sectors on the territory of Thua Thien Hue in the coming decades.

e) Propose strategy and solutions to adapt to climate change and mitigate climate change in the coastal zone in the social-economic sectors and environment of the Huong River basin, Thua Thien Hue Province and in Phu Vang District, Thuan An Town and the Chan May – Lang Co Economic Zone.

g) Organize workshops to propagandize and disseminate the knowledge on climate change, especially its adverse impacts, strategy and solutions to adapt to climate change in social-economic and environment activities of Thua Thien Hue, particularly the coastal zone.

h) Organize investigation on awareness on climate change and stakeholders' opinions on the integration climate change information and adaptation measures into socio-economic development strategy, particularly ICZM strategy of Thua Thien Hue Province.

Almost all results of the above-mentioned project activities are summarized in 28 reports of special subjects.

(5) The project was completed with the main contribution from the following organizations:

- IHMEN, the implementing agency which designated by the Ministry of Natural Resources and Environment (MONRE) as the focal point to develop and implement the project.
- Department of Natural Resources and Environment (DONRE), Department of Science and Technology (DST), Department of Agriculture and Rural Development (DARD), Department of Industry (DI), Department of Tourism (DT), Hue University of Sciences, Management Board for the Huong River project, Thua Thien Hue Province.
- The People's Committee and the Bureaus and Boards of Phu Vang District.
- The Netherlands Climate Assistance Program (NCAP)

(6) The Final report was prepared on the basis of the achievements of researches of special subjects, the reports, documentation and data of many sectors.

Moreover, this report has used some following important documents:

- Statistical Yearbook 2006 of Thua Thien Hue Department of Statistics,
- Natural disasters in Thua Thien Hue of Center for Hydro-Meteorological Forecasting of TTH Province.
- ICZM Strategy of Thua Thien Hue Province,
- Report to assess the works on directing the flood and typhoon prevention and preparedness and mitigation of natural disaster in 2006
- Direction and tasks of flood and typhoon prevention and preparedness and mitigation of natural disaster in 2007 of Thua Thien Hue Province of the Committee for Flood and Storm Control, Search and Rescue (CFSCSR) of Thua Thien Hue Province,
- Report on damages and the overcoming of consequences of rainfall and floods from October 13 to November 16, 2007 of the People's Committee of Thua Thien Hue Province.
- Study results on climate change and its impacts to water resources, ecosystem, and social economic activities of Thua Thien Hue province
- Analyzing impacts of climate change on Huong River flow-focusing on Phu Vang district, result of the study, Oct. 2007
- Analyzing and processing the existing observation data in Thua Thien Hue province, result of the study, Oct. 2007
- Investigation and survey collection results of stakeholders
- Some suggested general adaptation measures to climate change impacts on coastal and lagoon areas and message to policy makers in Thua Thien Hue
- Supported information about climate change, scientific research results about climate change in Thua Thien Hue province and Phu Vang district and improve knowledge and adapt with climate change for local people
- Meeting materials
- Stakeholder awareness raising on climate change and adaptation measures in Phu Vang district, Thua Thien Hue province
- Collected information about ICZM Revision Procedure, report on investigation survey results.

- Document explaining the backgrounds and rationale for revising the ICZM Strategy and Action Plans (Report on branches: Tourism, Transportation, Construction, Agriculture, Ecology…)

- Stakeholder Consultation Plan

- Stakeholder Consultation Report

- DONRE final report: Climate change integration on ICZM strategy in sustainable development

- Report on “Stakeholders consultation on integration of climate change to social economic development program and ICZM in Thua Thien Hue province”

(7) Final Report of the project is presented in 5 chapters with the following main contents:

Chapter 1: Natural and socio-economic characteristics of Thua Thien Hue Province and Huong River basin. This chapter presents the important natural characteristics: topography, geology, soil, climate, hydrology and some main socio-economic conditions: population, population growth, economic growth, present conditions and direction of development of agriculture – forestry – fishery, industry – construction and resettlement. Chapter 1 also preliminarily addresses biodiversity status in Thua Thien Hue.

Chapter 2: Natural disasters and their impacts in Thua Thien Hue. This chapter introduces the conditions for the formation and increase of natural disasters, space and time distribution and impacts of the main natural disasters: typhoon, thunderstorm, drought, salinity intrusion, flood, flash flood, landslide, erosion of river bank and seashore.

Chapter 3: Overview on climate change in Viet Nam and Thua Thien Hue. This chapter presents the manifestations of climate change in many recent decades and scenarios of climate change in the coming decades on global scale as well as in Viet Nam and Thua Thien Hue Province.

Chapter 4: Climate change impacts in Thua Thien Hue. Climate change impacts mentioned in this chapter include the increase of extreme hydro-meteorological elements, the main natural disasters such as typhoon, whirlwind, sea level rise, and their direct effects on ecological elements, coastal zone, and the principle socio-economic fields in Thua Thien Hue Province. This chapter also presents Climate change impacts on Phu Vang District, the point of project and the Chan May – Lang Co economic zone.

Chapter 5: Policy and solution to adapt to climate change in Thua Thien Hue. This chapter presents the solutions to adapt to climate change in the areas and sectors that have had the climate change impacts assessment in the Huong River, Thua Thien Hue Province and especially Phu Vang District. The recommendations on integration of adaptation to climate change into ICZM are also introduced in the final part.

At the final of the report there are conclusion, recommendation and lessons-experiences are withdrawn from project activities.

(8) Final report was prepared by a team of the project experts, including the International Technical Advisor under the direction of the project Director and Project Management Unit.

In its process of implementing of the project we have received the wholehearted assistance from the Leadership of IHMEN, leaders of the People's Committee, the Departments and Boards of Thua Thien Hue Province, leaders of the People's Committee, Bureaus and Boards of Phu Vang District and from CTA and NCAP Experts. Sincere gratitude is expressed to all on the occasion of completion of the project.

CHAPTER 1: NATURAL AND SOCIO-ECONOMIC CHARACTERISTICS OF THUA THIEN HUE PROVINCE AND THE HUONG RIVER CATCHMENT

1.1 Natural characteristics

1.1.1 Topography characteristics

Thua Thien Hue is a province in coastal area of Northern Central Vietnam, limited in 15059’ - 16048’N and 106025’ - 107051’E, bordered with Quang Tri Province to the North, Da Nang City, Quang Nam Province to the South, The People’s Democratic Republic of Laos to the West and the East Sea to the East.

Lying on the East – West corridor connecting Myanmar, Thailand, Laos, Viet Nam with the East Sea, Thua Thien Hue is one of four provinces of the key-point economic zone of the Central and one of the big cultural and tourism centers of the country.

Thua Thien Hue has an area of 5054km2, including 8 districts: Phong Dien, Quang Dien, Phu Vang, Huong Thuy, Huong Tra, Phu Loc, A Luoi, Nam Dong and Hue City with relatively complicated topography.

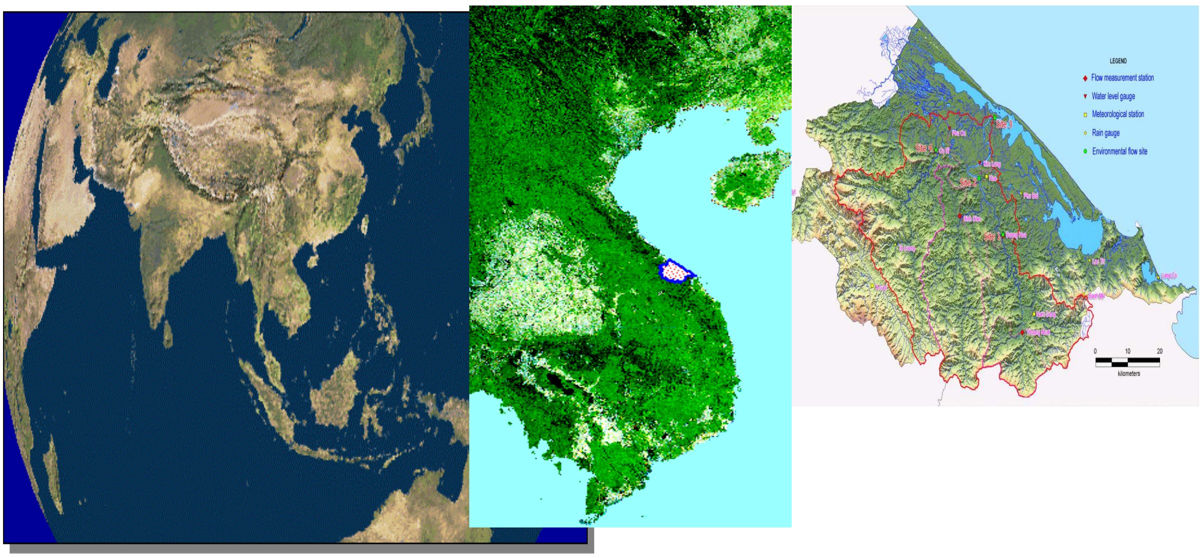

Figure 1.1: Thua Thien Hue province location and geography

Huong River has a catchment area of about 3000 km2, limited in 15059’–16036’N and 107009’ - 107051’E. Huong River Catchment is adjacent to the lagoon system Tam Giang–Cau Hai to the North, Da Nang City, Quang Nam Province to the South, Asap–A Luoi River Catchments and O Lau River Catchment to the West and Nông River Catchment to the East, including all or a part of districts: Nam Dong, Huong Thuy, Phu Vang, Phu Loc, Phong Dien, Huong Tra and Hue City.

On the territory of Thua Thien Hue, all mountain ranges and stretches of plain have the direction of Northwest - Southeast, parallel to the coastline, therefore the topography is gradually lower from the West to the East.

1.1.2 Areas of territory

On the territory of Thua Thien Hue and Huong River Catchment in particular, there is the formation of areas in West – East direction: mountainous area, hilly area, plain and coastal lagoon and sand dunes.

Figure 1.2: *Huong River*

1.1.2.1 Mountainous area

Occupying 70% the West and South area of the province; the Western mountainous area is a part of the Truong Son Mountain Range with many high peaks, of which, Dong Ngai peak is 1,774m and Dong Pho peak is 1,346m. The Southern mountainous and hilly area is Bach Ma Range starting from the Truong Son Mountains protruding to the sea with the peaks higher than 1000m, separating Thua Thien Hue from Da Nang: The distance from the high mountainous area down to the coastal plain is only less than 50km, creating a relatively great slope for Huong River Catchment. The land with slope above 250 making up 55.4% of the area, so most of land in mountainous and hilly area is eroded and degenerated.

1.1.2.2 The plain

The plain of Huong River has an area of about 500km2 accounting for around 17% catchment area divided into two parts: Northern Huong River and Southern Huong River. On the Northern Huong River, in the plain, the elevation of rice field is from (-) 0.4–(+) 2.5m and the large inland sand area has elevation from (+)4.0 to (+)8.0m.

Figure 1.3: *Huong River plain- rise paddy*

The Southern Huong River is a hollow area and gradually sloping from Huong River to Cau Hai Lagoon, with many small rivers and streams. In comparison to Northern Huong River, the Southern Huong River is more depressed, with many “hollow areas” with the bottoms having elevations from (+)1.0–(-)1.5)m.

1.1.2.3 The area of lagoon, inland and coastal sand dunes

This area has 3 lagoons linking together: Tam Giang, Dong and Cau Hai (in some localities, they are called Sam Swamp and Chuon Swamp). On the map, there are not any signs to clearly differentiate 3 lagoons from administrative borders. Tam Giang–Cau Hai Lagoon has an area of 22,000ha, the widest place is 8- 9km, the narrowest 0.5 – 0.7km, it connects to the sea mainly by Thuan An and Tu Hien Estuaries. In history, Thuan An, as well as Tu Hien estuarine, is not stable, they are opened in this place or other from time to time, the water depth in low flow season ranging between 1.5 and–2m, and 3–5m in flood season, respectively. All big rivers in the area such as O Lau, Huong, Nong and Truoi Rivers pour into Tam Giang Lagoon before going to the East Sea.

The coastal sand area is mainly a series of sand dunes from Huong Dien (the limit between Quang Tri and Thua Thien Hue) to Tu Hien Estuary (Phu Loc District) which is 71km long and about 2.5km wide. Adjacent to these sand dune series to the Northeast is the

East Sea, to the West are villages from Dien Huong to Vinh Hien with 20 communes under 5 districts: Phong Dien, Quang Dien, Huong Tra, Phu Vang and Phu Loc.

1.1.3 Characteristics of geology and soil

Soil and rock are mainly Paleozoic and Mesozoic sediment, widely distributed in the area. Paleozoic sediment includes A Vuong formation, distributed on a limited area in the Southeast of area, formation Dại Long distributed widely with two sub-formations.

- The upper sub-formation, with the main component of much clay shale rock alternated with aleurolite and sandstone.

- The lower sub-formation has bigger distribution with two components of sandstone sediment, few minerals and few clay-with-flints.

Devon sediment creates long stretch along the catchment with components changing from grit pebble, clay-with-flints or sandstone in lower layer, to aleurolite alternated with sandstone in mid layer, gradually transferring to aleurolite, clay-with-flints, argillaceous limestone and limestone in the upper layer.

Magma intrusions are distributed in many blocks with different dimensions. The tertiary sediment is mainly in coastal plain including pebbly sand, sand, clayey silt and humus.

The land is mainly different kinds of light yellow ferralite soil on the weathering products of sandstone, schist or other stones, in general poorly fertile, the layer of soil is often thin; in many places, the process of lateritization happens quite strongly. However, a not large area in the valley of Nam Dong District is the brown red ferralite soil on limestone, yellow red ferralite soil on clay-with-flints with the thicker layer of soil and may be better used for agriculture production; at the same time it makes the water turn brown red – yellow colors, especially during rainfall and flood period. The meat earth mixed with clay in Northern Huong River and Southern Huong River is suitable for cultivation, especially for rice the plant requires a relatively high fertility. However, in many places, the soil is impoverished due to activities of exploitation and severe hydro-meteorological conditions. This kind of land is not suitable for agriculture. Land in high area is suitable for vegetable, other crops and fruit trees. The hilly area in the West and South and the jungle has the kind of grey yellow soil created on the eroded sandstone and ferralite, that is covered by a thick vegetation. During the war, the toxic chemicals had destroyed a lot of plant making this hilly area bare. In general, the land of the Huong River Catchment belongs to poor nutrition and diversified.

Thua Thien Hue has 49,107ha agricultural land and 180,412ha forest land (Table 1.1). Other districts in plain are often flooded except for Nam Dong. The plain of Huong River is lower than the sea level and flood level so mostly is inundated in the alert level 3 (the alert level 3 is 3,00m in Hue), and up to 2/3 population and 2/3 houses in the catchment are inundated when big flood occurs.

Table 1.1: *Distribution of land in Huong River Catchment (ha)*

District/ City	Total natural land	Of which					Note
		Agricultural land	Forestry land	Special use land	Residential land	Not yet used land	
Phong Dien	95,375.11	10,235.75	36,026.69	3,768.61	396.85	44,929.53	Include 16/16 communes
Quang Dien	16,307.70	6,64.32	1,326.70	2,019.48	375.59	5,971.61	Include 11/11 communes
Hue	7,098.78	2,710.00	469.25	2,133.35	1,038.14	748.04	Include 25/25 communes
Phu Vang	19,433.80	8,063.21	598.20	2,981.37	360.95	7,439.37	Include 13/20 communes
Huong Thuy	45,733.80	5,630.91	21,610.46	3,202.62	361.85	14,927.96	Include 12/12 communes
Phu Loc	72,808.00	8,426.60	33,276.50	2,681.25	521.90	27,902.25	
Huong Tra	24,148.40	6,119.27	5,357.81	2,442.81	379.20	9,989.95	Include 18/18 communes
A Luoi	122,901.18	5,221.53	73,561.61	733.53	43,385.13		Include 21/21 communes
Nam Dong	65.052,2	3.193,9	41.935,9	305,1	83,4	19.533,5	Include 11/11 communes

1.1.4 Characteristics of climate

1.1.4.1 General characteristics

Thua Thien Hue is totally located inside tropical latitudes and is the transition area from the Northern climate to the Southern one.

The most important role in the climate of Thua Thien Hue is played by the western and southern mountain ranges. In winter, the mountain ranges makes the Northeast wind direction change into the Northwest direction, the cold air mass stays in the East of the Truong Son Range and North Hai Van Pass, causing heavy rain and flood by the end autumn–early winter, making the rainy season diphase in comparison to general situation in the North, Tay Nguyen, the South and creating one of the biggest rainfall centers of the entire country.

In summer, the mountain ranges cause the "fern" effect leading to extremely dry and hot weather accompanied by drought.

The diversified and divided topography of Thua Thien Hue province are also the cause of differentiating the climate in space that creates many different sub-climatic areas. In general, the climate conditions are very severe, every year typhoon, sunshine, heat, drought and flood cause many difficulties for all socio-economic activities.

1.1.4.2 Wind characteristics

The prevailing wind direction in Thua Thien Hue changes clearly according to season. Due to mountains surround to the West, the South and many mountain ranges protrude to the sea dividing the territory into many parts, the wind direction is significantly dispersed.

Maximum wind speed is up to more or less 30m/s in typhoon, whirlwind and 15–20m/s in some times of strong Northeast monsoon.

1.1.4.3 Temperature characteristics

Thua Thien Hue has relatively rich radiation of a territory lying quite deeply in the solstices of the Northern hemisphere. Annual average temperature, including the mountainous area which has a decrease in temperature with the height following the gradient of 0.50C/100m, is about 17-25.50C, achieves the tropical criteria in general and temperature of high mountain for the mountains with height more than 600m.

1.1.4.4 Rainfall characteristics

Thua Thien Hue is one of the provinces with the largest amount of rainfall in the country with annual average rainfall of 2800–3400mm. The rainfall below 2800mm happens in some Northeast plains in the districts Huong Dien, Quang Dien, Phu Vang, and Hue City (Table 1.2). The rainfall above 3400mm is in the famous rainfall center Bach Ma. According to observation data of many recent years, the rainfall of Bach Ma is no less than 5000mm.

Table 1.2: *Annual and monthly rainfall (mm)*

Location	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Co Bi	100	50	43	66	163	156	118	116	442	868	624	203	2,959
Phu Oc	93	60	35	85	135	100	102	153	314	841	509	271	2,689
Hue	95	48	34	47	104	125	71	120	335	762	562	252	2,555
Phu Bai	170	76	54	59	77	97	110	121	413	778	515	303	2,773
Loc Tri	187	53	20	63	189	225	75	95	531	924	779	295	3,436
Binh Dien	95	22	19	49	133	204	79	146	410	767	617	224	2,765
Ta Lương	65	50	11	148	146	250	72	105	305	1127	879	174	3,332
A Luoi	65	32	63	142	227	202	170	181	398	900	611	251	3,242
Nam Dong	97	47	52	93	210	250	171	204	392	1044	656	238	3,454

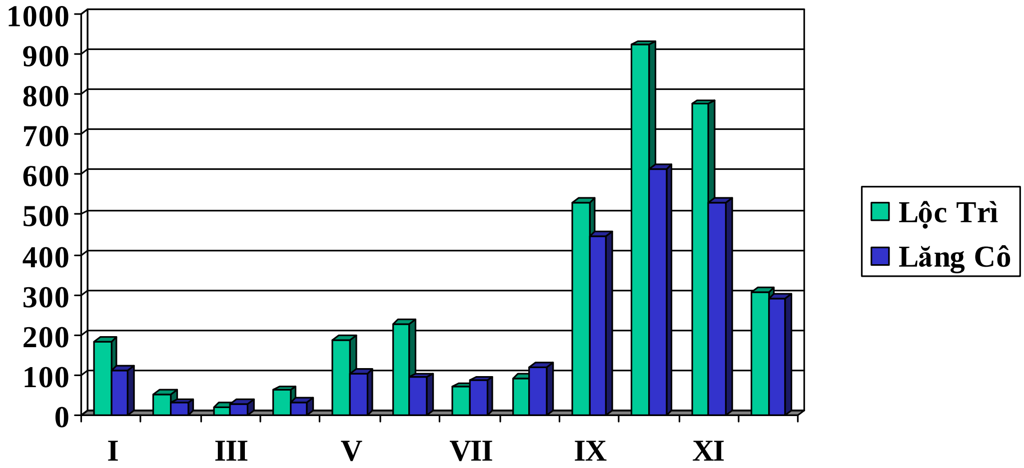

Figure 1.4: *Monthly rainfall at Lang Co and Loc Tri station (mm)*

1.1.4.5 Number of rainy days

In general, the distribution of rainy days is suitable for rainfall distribution. On average every year there are about 200–220 rainy days in mountainous area, 150-170 rainy days in the plain. In rainy season months, each month has 16–24 rainy days, in dry season, each month has 8–16 rainy days.

In Thua Thien Hue, two areas with different rainy seasons exist:

- In coastal plain the rainy season starts from September and ends in December, lasting 4 months and dry season from January to August, lasting 8 months.

- In mountainous area, the rainy season starts from May or June, and ends in December, lasting 7–8 months, dry season from January to April or May, lasting 4–5 months.

Rainfall in Thua Thien Hue has considerably big intensity, especially in rainy season. The record of rainfall with the duration of 10 minutes is 19–30mm, 30 minutes 32–54mm and 60 minutes 70-96mm, relatively low in the plain and high in mountainous area. The record of daily rainfall in Thua Thien Hue is 730.7mm, of the highest ones in our country.

Table 1.3: *Some maximum rainfall characteristics (mm)*

Location	10 minutes	30 minutes	60 minutes
Hue	19	32	70
Nam Dong	24	54	77
A Luoi	30	54	96

Rainfall in Thua Thien Hue highly concentrates in rainy season months; In the middle of rainy season there may be the duration without rainfall lasting 11–15 days (Table 1.4).

Table 1.4: *Maximum time of no rainfall (day)*

Location	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Hue	8	24	31	21	26	20	17	10	18	7	6	12	31
Nam Dong	12	11	17	19	13	9	13	10	11	6	11	9	19
A Luoi	10	23	20	15	9	11	12	18	13	11	15	12	23

1.1.3.4 Potential evaporation

Annual average evaporation in the plain is about 900-1000 mm, in mountainous area about 800–900mm, equal to 30–40% of annual rainfall. Annual variation of evaporation is contrary to annual variation of rainfall: The least evaporation during the period of the biggest rainfall and vice versa. In the months with the biggest rainfall (IX–X) the popular evaporation is 40–70mm/month and in V–VII the popular evaporation is 100-150mm/month. Much evaporation, little rainfall and high temperature cause a severe drought period in coastal plain.

1.1.3.5 Some special weather phenomena

1) Typhoon: According to data of 35 years (1952–2006) the annual average number of typhoons landing on Binh Tri Thien (Quang Binh, Quang Tri and Thua Thien Hue) is 0.63. Typhoon only appears from May to November, at most in September and October (Table 1.5).

Table 1.5: *Number of typhoons landing on Binh Tri Thien during 1952-2006*

Number	V	VI	VII	VIII	IX	X	XI	Total
Number of typhoon	3	4	3	4	10	8	3	35
Proportion (%)	9	11	9	11	29	22	9	100

The number of typhoons and tropical depressions affecting Thua Thien Hue is not big, but their damages are very significant due to high wind speed and rainfall. The maximum wind speed in the typhoon TILDA on 22 Sept 1964 came up to 38m/s. When a typhoon lands on Thua Thien Hue, the average rainfall is 200–300mm, if it is combined with a cold front, it can be up to 500–600mm. Apart from that, the sea level rises up very high, sometimes up to 1.9m as in Thuan An and 1.7m as in Lang Co.

2) Tropical convergence: As tropical convergence occurs, on the sky there is an area of dense cloud of hundreds km wide, causing heavy rainfall on a large area. In Central Vietnam in general and Thua Thien Hue in particular, this kind of weather often happens in September and October, sometimes in May and June. Activity of tropical convergence in early summer months (V, VI) in Central Vietnam combined or not combined with cold front by the end of season is the cause of grain fill rainfall.

3) Hot and dry Westerly: This is a special weather pattern representing the weather condition in the Middle of Vietnam. Hot and dry westerly appears from the last ten days of February and ends in the first ten days of September in depressed valleys and plain. The feature of hot and dry westerly is high temperature, low humidity, and wind of West direction. At noon or afternoon, the highest air temperature can be over 350C, sometimes over 38–400C, the lowest humidity below 60% or less. In average every year Hue City has about 35 days and Nam Dong has 55 days with hot and dry weather. Hot and dry Westerly has strong activity in the plain from May to August, at most in June (10 days) and in the depressed valley Nam Dong from March to August, at most in July (12 days). On average each hot and dry

Westerly happens from 3 to 5 days in mid season and 2–3 days in early and end of season. There are cases in which hot and dry Westerly lasts more than one month leading to severe drought.

1.1.5 Characteristics of hydrology and water resources

1.1.5.1 Characteristics of runoff

Runoff can be under many different forms: Annual discharge Q (m3/s); annual runoff module M (l/s–km2); runoff depth Y (mm); annual runoff coefficient @ = Y/x (x is annual rainfall); total runoff W(m3).

Characteristics of runoff on the main river catchments in Thua Thien Hue are shown in Tables 1.6 and 1.7.

a. Annual runoff

With area bigger than the ones of other rivers, Bo River has the annual discharge up to 56.0m3/s. Huu Trach River also has annual discharge of 41.1m3/s, bigger than Ta Trach and Truoi Rivers.

Between the rivers there are not significant differences in other characteristics of annual runoff.

The runoff is not evenly distributed for various months in a year. In Thua Thien Hue, it is possible to differentiate two seasons: flood season from October to November and low flow season from January to September.

b. Runoff of flood season

The proportion of flood season runoff over annual runoff comes up to 69.1% on the Bo River, 66% on Huu Trach River and 64% on Ta Trach River. Flood season only lasts 3 months but flood can happen in many other months, including:

Early flood: appears in September with frequency of 30%, often lasts 1–3 days.

Late flood: appears by the end of December to early January, with small intensity and amplitude.

Grain fills flood: appears from the end of April to early June, with small intensity in alert level I.

c. Low flow season runoff

The proportion of low flow season runoff over annual runoff is about 30% in Bo River, 34% in Huu Trach River and 36% in Ta Trach River.

Although in low flow season, the rainfall of all season also comes up to 800-1000mm in mountainous area of Nam Dong–A Luoi and 600–700mm in the plain due to relatively big rainfall after the principal rainy season (January) and rainy season of grain fills (IV-VI).

Variation of low flow season runoff has the form of two bottoms corresponding to 2 dry periods: from March to April, before grain fills rainy season and from July to August, when the hot and dry Westerly prevails (Table 1.8)

Table 1.6: *Characteristics of annual runoff of some main rivers in Thua Thien Hue*

River	Station	Area of catchment calculated to measurement station (km^2)	Q (m^3/s)	Y (mm)	M (l/skm^2)	@ = Y/X	Cv
Ta Trach	Thuong Nhat	186	15.2	2580	81.7	0.73	0.302
Huu Trach	Binh Dien	570	41.1	2274	72.1	0.73	0.312
Bo	Co Bi	720	56.0	2453	77.8	0.78	0.302
Truoi	Truoi	74	11.6	2613	82.8		0.309

Table 1.7: *Distribution of runoff according to season of some stations (average of many years)*

Station	Flood season				Low flow season			
	Time	Q(m^3/s)	W(10^6)	α (%)	Time	Q(m^3/s)	W(10^6)	α (%)
Thuong Nhat	X-XII	36.6	291.1	63.6	I-IX	7.07	167	36.4
Co Bi	X-XII	196.0	1.419.0	69.1	I-IX	27.3	637	30.9
Binh Đien	X-XII	123.0	971.0	67.4	I-IX	21.5	506	34.3

α: Seasonal runoff/ Annual runoff

Table 1.8: *Monthly discharge in low flow season*

River	Position of observation	Q month III (m^3/s)	Q month IV (m^3/s)	Q month VII (m^3/s)	Q month VIII (m^3/s)	Q of the driest month (m^3/s)
Bo	Co Bi	15.73	14.65	11.59	13.74	4.0
Ta Trach	Thuong Nhat	3.76	3.71	6.08	6.63	1.42
Huu Trach	Binh Dien	15.04	13.40	14.30	14.90	4.53

1.1.5.2 Characteristics of water level

Water level of flood: Every year in Thua Thien Hue in average there are at least 7 floods from alert level II (Kim Long Station–Huong River). The average duration maintaining the flood level on the river at alert level II in a flood in the plain is 3, in some floods up to 9 days. The variation of flood level every year is relatively big.

Water level of the rivers in low flow season: Every year, on the rivers there are two times of low flow: the period from February – April and period from July – August In these two periods, water level depends on the tidal regime. On the Bo River (Phu Oc Station) and Huong River (Kim Long Station) water level of tidal peak mainly depends on sea tide. While the water level of tide foot depends on water level coming from upstream. Due to flat topography and the river bed deeper than sea level, the tide goes deeply into the land creating two-direction flows in the river and salinity intrusion.

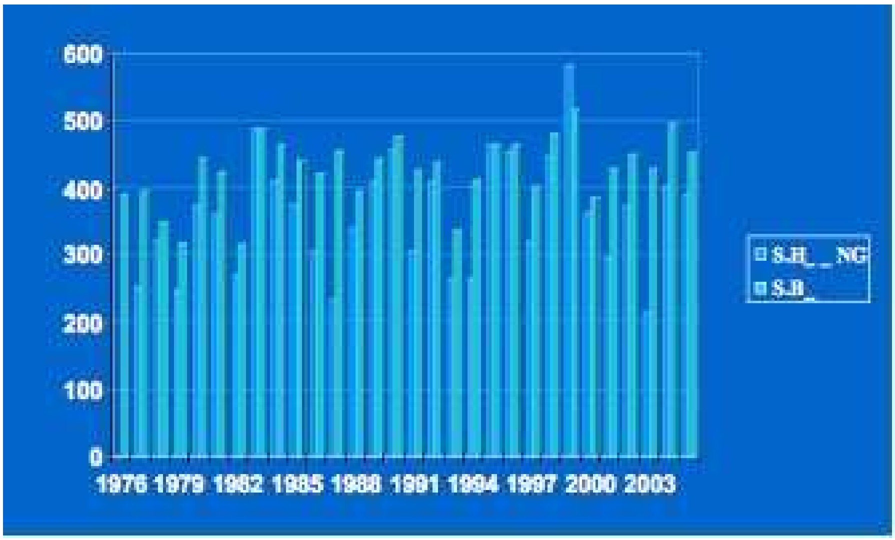

Figure 1.5: *Flood water level on Huong and Bo River*

1.1.5.3 Characteristics of tide

The coastline of Thua Thien Hue is only 120km in length, but the tide has very complicated evolution. To the North, from South Quang Tri to Thuan An Estuary, the tidal regime is irregular semidiurnal form, almost all the days in month semidiurnal tide with average magnitude of 1.2–1.6m, decreasing to the South. The coastal area, neighboring to Thuan An Estuary, belongs to regular semidiurnal regime, each day has two times the tide goes up and two times goes down. Tide fluctuation here is the smallest on the whole coastal line of the country. Daily amplitude of water level at Thuan An Estuary is only about 30–50cm, at the area of Tu Hien it is bigger, but only about 55–100cm. In the Southern area, the tide changes into diurnal with 20-25 days of diurnal tide/month, fluctuation amplitude in springtide is 80cm. At Chan May area, average amplitude is 70cm, maximum 145cm and minimum 20cm. Here, average tide level is 0.0cm and maximum is 126cm, minimum (-)72cm.

The wave regime is affected by monsoon regime. In the winter, in the coastal area, the wave of North and Northeast directions prevails. In Thuan An Estuary, the wave of Northeast direction has frequency of 99% and the height of 0.25–3m. In summer the wave direction is mainly Southwest and Southeast in the open sea, Southeast in coastal area. In Thuan An area, the wave of East direction with the height of 0.2–1,0m has frequency of 99%.

The tidal current has irregular semidiurnal and regular diurnal features, for the area neighboring Thuan An Estuary, it is regular semidiurnal. The tide current speed is quite strong, in average 25–39cm/s, 10-15m in area of deep water and gradually decreases offshore. The fully diurnal and semidiurnal tide currents have the same level in Thuan An Estuary, achieve 15–20cm/s. Going further into Tam Giang Lagoon, the fully diurnal is only 3cm/s, while the semidiurnal tide current comes up to 25–30cm/s. In Tu Hien Estuary, the semidiurnal tide current achieves 35-40cm/s. At Chan May Port, the maximum tide current only achieves 12–22cm/s. The tide current plays the principal role in the process of transporting sandy mud in the surf. The wave direction is relatively stable along the coast with season. In summer, the wave current directs from the South coast upward (SE–NW), in winter, the direction is on the contrary (NW–SE). The wave current speed fluctuates from 30–100cm/s and achieves the greatest value in the season of Northeast monsoon. In Chan May bay, the speed along the coast achieves maximum due to the wave runs toward the West up to 57cm/s and toward the East at 31cm/s.

1.1.5.4 Natural resources and present conditions of water environment of the Huong River

Water resources of the Huong River catchment, including groundwater, and surface water coming from tributaries with the amount depending on season, play an important role in the life of people in the province. The water source from the Huong River supplies for 3 water plants of Hue City: Van Nien, Quang Te and Gia Vien, for many areas of people living along two riversides from upstream to downstream and use in many other purposes: agriculture, industry, tourism and navigation... The groundwater plays an important role in supplying water for the living in many areas far from the river.

The water source of the Huong River is mainly from the rivers Ta Trach, Huu Trạch, Bo, and Nong ... with discharge changing according to rainfall. Every year, there are two distinct seasons: In flood season, high flow often causes inundation, in low flow season, low flow leads to drought, lack of water and salinity intrusion far into the land.

The flood season discharge is biggest at Tuan confluence, up to 12,000m3/s. At Co Bi this value is 4,500m3/s. During recent 50 years, on the Huong River there were many big flood events. At Kim Long, the frequency of water level over +4.5m has been on increase.

In comparison to the coastal rivers in Central Vietnam, the system of Huong River has the biggest content of low flow water. The low flow season discharge at Tuan confluence is 8–9m3/s. Total water volume of the Huong River Catchment during 8 months of dry season only remains 400–600 million m3 occupying 18–20% total annual amount.

According to data on water quality in 1996–1999 of Department of Science and Environment of Thua Thien Hue Province, the salinity of Huong River is affected by the irregular semidiurnal tide regime, with the biggest tide amplitude up to 60-80cm. Therefore, salt water goes up to Thien Mu Pagoda, especially in dry years such as 1994, salt water can go beyond the Gia Vien Water Plant. Presently, with the operation of Thao Long Dam, salinity intrusion on Huong River has decreased significantly (saline water does not intrude far towards upstream Huong River and the duration of salinity intrusion does not last long as formerly).

Average salinity in positions downstream (from Gia Vien) increases gradually from beginning of low flow season and achieves maximum at about August In front of Thao Long Dam, the average maximum salinity at two above-mentioned times is 6.55 and 6.74‰.

According to report of the Department of Science and Environment of Thua Thien Hue Province, water quality of Huong River before flowing through Hue and in tributaries such as Ta Trach, Huu Trach, Bo and Loi Nong Rivers is slightly affected by wastewater from production and domestic use so it is pretty good, and can be used for purposes of drinking and and production. However, water quality of Huong River after going through some places in Hue City drops down quickly: COD gradually rises through locations of Van Nien–Gia Vien–Freeze Plant (from 3.6±2.8 to 6.1±3.2mg/l), total coliform also goes up, from 6860 to 1294 MNP/100ml. In this part of river, the water is seriously polluted due to domestic wastes, human and animal manure, and industrial wastewater (aqua-product processing, producing beer, and mechanical manufacturing...)

Apart from the above-mentioned parameters, the content of NH4+, NO2-, PO43-, and organic substances in the water of Huong River is also high, causing negative effects on quality of water supply. In low flow season, the discharge of Huong River decreases significantly, on many parts of Huong River, particularly the one going through Hue City, there is the phenomenon “blooming algae” leading to the dark green color that features the eutrophic water.

The heavy metal elements are only investigated recently and preliminary discovered at low concentrations, not yet dangerous. It is necessary to carry out further survey to have accurate conclusion. The elements related to the plant protection chemicals, and organic toxics have not been controlled so they have not yet been evaluated, but through the inspection of local using of plant protection chemicals it is possible to conclude that the pollution of Huong River water due to plant protection chemicals is inevitable.

Box 1.1 Biodiversity in Thua Thien Hue

Area of forest and agricultural land is 352,680ha, in which there are 51,268ha of protection forest, 70,029ha special use forest and 21,345ha production forest; forest cover is up to 43%. Thua Thien Hue has a system of areas for biodiversity conservation and national parks. Bach Ma National Park, Phong Dien Natural Reserve, North Hai Van Landscape Forest, and Southwest Thua Thien Hue Landscape Forest... Moreover, there are also landscape forests for protecting cultural and historical relics, tombs and royal palaces and forests of Truong Son Mountain Range, the habitat of rare and valuable species: tiger, panther, gibbon, hylobatates concolor, white grey pheasant and other newly discovered species: Sao-la, big deer, Truong Son deer...

Thua Thien Hue has particular interesting and charming natural landscape with many famous sites: Huong River, Ngu Mountain, Hai Van Pass, Bach Ma Mountain, Thuan An Estuary, Lang Co Beach, Canh Duong, and Cau Hai–Tam Giang Lagoon.

In biodiversity, Thua Thien Hue has 3 typical areas: Green belt, Cau Hai–Tam Giang Lagoon and Son Tra–Hai Van.

The Green belt lies between Phong Dien Natural Reserve and Bach Ma National Park, has 134000ha, belongs to three districts: A Luoi, Nam Dong and Huong Thuy.

The World Wild Life organization (WWF) considers this place as an area of vital importance in the long term conservation of rare and valuable species such as Sao La, white grey pheasant, Truong Son striped rabbit and bamboo partridge of Central Vietnam, at the same time it is an important habitat of many other rare and valuable species such as Asian elephant and tiger...

The Green belt contains many important ecosystems, including lowland which the International Bird Organization lists in the global important bird regions, the distribution area of very precious bird species with special restrict features, some of them only exist in the area of a province and not in any other areas of the world.

The system of Tam Giang–Cau Hai Lagoon is an area of coastal flood land, brackish water, tropical monsoon area, having high values in natural resources and particularly biodiversity.

In Tam Giang–Cau Hai Lagoon, there are 947 biological species, including 250 phytoplankton, 66 zooplankton, 54 bottom plants, 179 bottom animals, 46 sea weeds, 31 high class plants, 18 water weeds, 230 fish species and 73 bird species.

This is the habitat of many migrating birds, including about 30 species under protection: purple heron, kite-fisher, brown back yellowlegs...

The system of Tam Giang–Cau Hai Lagoon is also a flood land with the biggest area and an area with the richest ecosystem and under most complete evaluation in Viet Nam.

Son Tra–Hai Van has a marine ecosystem of the third biodiversity on the entire country. It has 140 coral species of 63 genera and 21 families. No other places in Viet Nam have coral growing densely along the coast with high frequency like here.

Apart from coral reefs with beautiful structure and thick density, there are also 245 micro-algae species, more than 70 zooplankton species, 135 sea weeds with great coverage, mollusks, crustaceans, echinoderms, sea turtle, especially a lot of coral reefs.

Sơn Tra–Hai Van area plays an important role in natural resources and ecology not only in Thua Thien Hue but also in Mid Central Vietnam.

1.2 Some socio-economic conditions

1.2.1 Overview on population

Population of Thua Thien Hue in 2006 is 1,137,962 people. The general population density of the entire province is 225 persons/km2, relatively high in districts of the plain such as Phu Vang (639 persons/km2), Quang Dien (564 persons /km2), the highest is in Hue (4,660 persons/km2), relatively low in mountainous districts, the lowest in A Luoi (33 persons/km2) and Nam Dong (35 persons/km2) (Table 1.9)

Urban population is 357,682 people, accounting for 31.4%. In general, male occupies 49.2%, less than 50.8% for female. It is noted that in Hue City and almost all other districts male is less than female while in two mountainous districts A Luoi and Nam Dong, it is on the contrary, female is less than male. The difference between male and female in districts is only about 1–2%, particularly in Quang Dien, Phong Dien and Hue City, it is up to 3–4%.

The entire province has 779,510 people at labour age, accounting for 68.5% population, mostly living in rural area, of which 67.8% participating in economic activities.

The rate of population growth in recent years, from 2004 to 2006, is only more or less 1.3% and it is encouraging that this rate has the decreasing tendency.

1.2.2 Gross product and economic development

Gross product in 2006 of Thua Thien Hue is 8,469 billion VND, in which agriculture–forestry–fishery only occupy 20.1%, industry and construction 36.1% and services up to 43.8%.

In recent years, not only gross product increased, but product structure also moved towards gradual increase in proportion of industry-construction and services, decrease in proportion of agriculture–forestry–fishery (Table 1.10).

Table 1.9: *Area (km^2), population (persons) and population density (persons/km^2)*

District/City	Area	Population	Population density
Hue	70.99	330.836	4660.3
Phong Dien	953.75	106.737	111.9
Quang Dien	163.07	91.989	564.1
Huong Tra	520.89	117.255	225.1
Phu Vang	280.32	179.137	639.0
Huong Thuy	457.34	95.336	208.5

Phu Loc	728.09	152.426	209.4
A Luoi	1229.02	41.129	33.5
Nam Dong	650.02	23.117	35.5
Total	5053.99	1137.962	225.2

Table 1.10: *structure of gross product in some recent years*

Year /Sector	agriculture–forestry–fishery	Industry-construction	Services
2002	22.9	33.0	44.1
2004	22.5	34.1	43.4
2006	20.1	36.1	43.8

The rate of economic growth in Thua Thien Hue is 11.2% in 2005 and 13.4% in 2006 significantly higher than 9.1–9.2% in 2002, 2003 and 2004.

Table 1.11: *Some main socio-economic indices in recent years*

Index	Unit	2002	2003	2004	2005	2006
Average population	Person	1091998	1103312	1117743	1126293	1137962
Growth rate	%	14.5	14.0	13.6	13.3	12.8
Gross product	Million VND	4,439,587	4,971,644	5,854,373	7,131,194	8,469,042
Economic growth rate	%	9.2	9.2	6.1	11.2	13.4
Value of agricultural production	Million VND	808,247	843,445	869,593	867,433	911,713
Yield of grain food	Ton	214,806	239,467	250,737	240,154	259,857
Yield of husky rice	Ton	210,829	235,736	246,490	235,029	252,604
Yield of husky rice per capita	Kg/pers.	193.1	213.7	221.1	208.7	222.0
Value of forestry production	Million VND	101,538	108,831	110,762	117,792	119,598
Area of concentrated planted forest	Ha	3554	3566	4,062	5,184	3,890
Area of scattering planted trees	Ha	2312	1,963	1,692	2,106	1,507
Value of fishery production	Million VND	330,233	413,289	445,468	461,195	533,581
Value of industrial production	Million VND	1852,817	2,126,591	2,465,915	2,856,624	3,354,492
Total capital invested for basic construction	Million VND	2,283,861	2717375	3086913	3495534	4750,000
Total export value	1000USD	40900	25745	37253	57119	200058
Total import value	1000USD	37429	33717	10327	58653	290570
Revenue from tourism - hotel	Million VND	302008	285090	37556	393409	410000
Total tourist number	person	655111	610565	758798	1050020	1165316

1.2.3 Present situation of sectors

1.2.3.1 Agriculture-forestry-fishery

Total production value of Agriculture-forestry-fishery in 2006 is 2645.402 billion VND, in which agriculture occupies 61.1%, fishery 30.6% and forestry only 8.2%.

Total value of agriculture production is 1,617.371 billion VND, in which cultivation occupies 67.6%, livestock 25.9%, the rest belongs to services of cultivation and livestock.

Cultivation includes annual plants and perennial trees. In 2006, area of annual plants was 64,498ha, including rice and other food crops and area of perennial trees is 13,262ha, including industrial and fruit trees.

Rice production is always the first and foremost activity in agricultural production in general and cultivation in particular. In 2006 the rice area was 50,241ha, in which 25,661ha winter spring crop; the rest is for summer-autumn and autumn crops. The average rice productivity of the entire province was 5.03 tons/ha, relatively high in districts Quang Dien, Huong Tra, Phu Vang, Huong Thuy and relatively low in districts: A Luoi, Phu Loc and Nam Dong. The rice yield of 2006 was 252,604 tons, 222kg per capita.

Apart from rice, in Thua Thien Hue there are 1,807ha maize, 4,668ha sweet potato, 7,075ha cassava, 2,131ha bean, 4,276ha peanut, hundreds of ha sesame, sugarcane and nearly 44,000ha vegetable.

Livestock breeding has more and more important position in agriculture in Thua Thien Hue. In 2006, the value of livestock production was 467.431 billion VND, equal to 28.9% value of agriculture production. Livestock breeding at most is buffalo, cow, pig and poultry. More than 36 thousand buffaloes and 28 thousand cows and oxen were raised in districts and Hue City, at most in Phong Dien and Phu Loc. More than 270 thousand pigs were raised in districts, at most in Huong Tra, Phu Vang, Phong Dien. The entire province has a number of nearly 1.4 million poultry.

In 2007 the value of forestry production was 217.767 billion VND, a little bit more than in previous years and still occupied less than 10% the value of agriculture-forestry-fishery production.

Forestry activity is mainly planting and taking care of forest, exploitation of wood and forestry products. In 2006, 3,890ha of concentrated forest and 1,507 ha of scattering trees were planted. Nearly 78% value of forestry production is from exploitation of wood and forestry products.

Value of fishery production in 2007 was 810.264 billion VND, significantly more than in 2004, 2005 and before, occupied 61.1% value of agriculture-forestry-fishery production.

Fishery activities are mainly catching on the sea and rivers, ponds, farming of shrimp, fish and other aqua-products.

In 2006 the catching was more than 24 thousand tons of aqua-products, more than half of which was from Phu Vang District (52.6%), a significant part was from Phu Loc District (21.9%), and Quang Dien District (8,2%). Shrimp was raised on an area of 3,000ha with an output of 3,800 tons. The area for raising fish was only half for shrimp with an output of nearly 3,200 tons.

1.2.3.2 Industry – construction

In 2006, value of industry production came up to 3,354 billion VND, nearly one and a half of the value of agriculture-forestry-fishery production.

There are 36,686 workers working in local industry foundations, mainly in mineral exploitation, food processing, construction, electricity and water supply...

In 2006 Thua Thien Hue Province produced 76 thousand tons of imenie ore, 27 thousand tons of Zincol Rutin ore; 10.2 million m3 stone; 162 million pieces of bricks; 904 thousand tons of cement; 84 million liters of beer of various kinds; 3.055 million liters of fish sauce; 800 tons of exported sea products; 21.5 million m3 of water....

In 2006 total capital invested for capital construction of Thua Thien Hue was 450 billion VND for more than 20 branches: agriculture, forestry, aqua-products, processing, mineral exploitation, hotel, credit, transport, finance, education, healthcare, culture and sport...The branches attracting a great deal of capital invested for construction are processing industry (18.3%), transport and store houses (15.2%), electricity and water (11.7%), hotel (10.1%), agriculture (8.7%), heath care and social welfare activities (4.5%).

1.2.4 Orientation of socio-economic development

On the basis of advantages as well as restrictions that affect the process of development in the coming time, the projection of economic growth during 2006–2010 would be 12–13%.

Orientation of development of branches is as follows:

Industry has the role of motive forces to promote other economic branches; average growth rate in 2006–2010 is 18–19%; that to the year 2010 it would achieve the proportion 49–50% of gross national product. In industry, develop branches with competition advantage and attracting many labours; give priority to investment in agriculture, forestry and aqua-product processing, construction materials and some new branches with high scientific and technological content such as biological technology and new materials; promote the building of industrial parks, encourage all economic components, invest to develop agriculture production. Agriculture–forestry–fishery grow in average 4-5% achieving the proportion of 9–10% of gross national product. Develop Agriculture–forestry–fishery in combination with social issues, guaranteeing the food security and poverty alleviation; increase the proportion of branches of professions and services. In agricultural activities, step up the application of scientific and technological progresses, continue to renew the structure of crops, livestock, crop pattern, stabilize the rice cultivation area at 50,000ha/year, develop the short term industrial trees, develop food trees, clean vegetable, fruit trees, orchids and bonsai trees, redistribute labours and move the people to hilly area, sandy area and inside rice field....

In forestry activities, strengthen protection and development of forest, especially riverhead protection forest, protection forest in sandy area and special use forest.

In fishery activities, give priority to investment in farming and processing for export, diversify various forms of farming in lagoon, on the sea, sandy area and rice cultivation with low effectiveness, concentrate to develop aqua-products to become key economic branch.

Tourism–services grow in average 8–9% each year and try to achieve the proportion 40-41% of gross national product in2010.

Develop in sustainable way tourism; bring tourism to become a key economic branch, develop tourism in combination with protection, improvement and preservation of Hue cultural character, and contribute to enhance the people’s life quality.

Activities to develop tourism include promoting the restoration and improvement of the community of Hue old Capital relics, strengthening investment into the group of national tourism Bach Ma–Canh Duong–Lang Co–Hai Van, build high quality hotels, enlarge the form of eco-tourism and build the strategy of international integration....

Orientation of developing various sectors includes: Develop material basis and infrastructure of transport, irrigation, post and communication, electricity, water supply and drainage; develop external economy, focus investment into Phu Bai Industrial Park, Encourage the development of Chan May economic and trade area and national tourist group Bach Ma–Lang Co–Hai Van; re-arrange structure of labors following direction of gradually increasing in areas of industry, construction and services, and decreasing in agriculture–forestry–agriculture, continue to socialize the affairs on population with direction towards the target of developing population in sustainable way; develop education both in scale, quality, form of training and material basis....

CHAPTER 2: NATURAL DISASTERS AND THEIR IMPACTS IN THUA THIEN HUE

2.1 Typhoon, whirlwind, sea level rise and their impacts

Annually, Thua Thien Hue has to cope with various natural hazards such as typhoons and/or tropical cyclones (in brief typhoon) coming from the Northwest Pacific and the East Sea of Viet Nam.

Not all typhoons generating in the Northwest Pacific and the East Sea affect Thua Thien Hue, but typhoon frequency as well as time of occurrence of typhoon in Thua Thien Hue depends on the spatial and temporal rule of activities of typhoons in the area where has been considered as the number one typhoon den of the world.

According to the assessment of the study: "Typhoon and typhoon prevention and preparedness" published in 1998, Thua Thien Hue belongs to area 3 among 4 typhoon areas of Viet Nam. This area stretches from Quang Tri to Khanh Hoa. Here, typhoons have rather complicated evolution: they gradually increase from March to July, become fewer in August, grow up in Sept, Oct. and last to Dec.

The above-mentioned estimation agrees with typhoon data of the period 1952-2006 which had been studied by the IHMEN. According to this data, typhoons often occur from May to Sept. most frequent in Aug., Sept, and Oct..

Like other localities, Thua Thien Hue has to face strong wind, heavy rain and storm surge caused by typhoons.

Rainfall during typhoon does not only happen in typhoon days, but also 1–3 days before or after typhoon. In Thua Thien Hue, rainfall in a typhoon on average is 150–200mm. It is not much compared with heavy rainfalls caused by other forms of weathers.Typhoon rainfall is especially heavy when typhoon coincides with cold airmass comming from the north at the end of autumn – early winter.

Many typhoons cause storm surge. During typhoon CECIL, the sea level rises by 3.1–3.3m, overflowing sea dyke, going further into the land 2–3km.

Whirlwind has not large scope of influence as typhoon, but it has very strong wind in combination with heavy rainfall, causing very significant losses. Whirlwind occurs more and more often, especially in El Nino years such as 1993, 1997, 2002.

From early 1993 up to now, on average every year there have been about 3–4 whirlwind in April, May or Sept., Oct., the transition months from winter to summer and vice versa. Some specific typhoon impacts were recorded:

The typhoon crossing Hue in October 19, 1903 made collapsed 4 spans of Trang Tien Bridge, 22,207 houses, 529 boats and ships sunk, 724 died

Typhoon CECIL landing on Vinh Linh in October 16, 1985 with wind scale 13 caused heavy losses for two provinces of Quang Trị and Thua Thien Hue, made collapsed 214 houses, 2 thousand class rooms, 200 healthcare foundations, 600 high tension poles, thousands of boats and ships sunk, 840 people died, 100 missing, 200 injured.

2.2 Drought, salinity intrusion and their effects

In order to summarize factors mainly related to drought as well as their changes by time, we use the drought index of months and years Ht = Pt/Rt. It is a ratio between Evapotranperation and rainfall amount

where:

Ht: drought index of month or year

Pt: Evaporation of month or year

Rt: rainfall of month or year

The ratio between Evapotranspiration and rainfall amount of year in Thua Thien Hue is around 0.25–0.4 (Table 2.1).

This ratio is observed below 0.25 in high and medium mountainous area where rainfall is much in the West and South; and it is above 0.40 in some plains and low mountainous areas in the North area close to Quang Tri. In Thua Thien Hue, due to the decrease of rainfall from Southwest to Northeast and the evaporation also gradually increases in this direction, This ratio is relatively low in the districts of Nam Dong, A Luoi and rather high in Phu Vang District...

Dry season, which is understood as the months with successive drought index over 1, i.e. from March to August in coastal plain districts, decreasing gradually toward mountainous district, only in few months in districts of A Luoi in the March and Nam Dong from the February to April

Table 2.1: *Drought index in Thua Thien Hue*

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Năm
Dong Ha	1.24	1.51	2.48	1.59	1.28	2.35	3.36	1.18	0.29	0.10	0.16	0.36	0.63
Hue	0.36	0.65	1.48	1.46.	1.13	1.20	1.70	1.18	0.21	0.08	0.08	0.13	0.36
A Luoi	0.59	0.98	1.02	0.45	0.60	0.62	0.98	0.67	0.16	0.04	0.04	0.10	0.27
Nam Dong	0.44	1.00	1.67	1.01	0.47	0.47	0.71	0.48	0.15	0.04	0.04	0.10	0.24
Da Nang	0.83	2.75	4.16	2.60	1.30	1.34	1.55	1.02	0.29	0.12	0.16	0.32	0.51

In order to evaluate the magnitude of drought, we use the criteria with the following specific conditions:

Ht winter (XI – II): Rt ≤ 10mm

Ht spring (III – IV): Rt ≤ 30mm

Ht summer (V – VIII): Rt ≤ 50mm

Here Rt is monthly rainfall

According to these criteria, drought on different areas of Thua Thien Hue and some neighboring provinces is mainly summer drought (Table 2.2).

Table 2.2: *Monthly drought frequency (%)*

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Đong Ha	0	57	54	15	50	43	64	47	0	0	0	0
Hue	2	11	46	40	60	54	62	40	0	0	0	0
A Luoi	0	31	31	7	0	7	29	14	0	0	0	0
Nam Đong	0	17	70	0	30	0	0	9	0	0	0	0
Đa Nang	0	24	77	68	70	64	67	47	0	0	0	0

In the same way other provinces in Northern Central Vietnam, drought in Thua Thien Hue is mainly accompanied by salinity intrusion which happens every year, particularly in El Nino years. Although it does not cause loss of life like typhoon and flood... drought has serious effects on national economic being: agriculture, industry, environment and health…

2.3 Flood and its impacts

According to data from 1977 to 2005, on the Huong River, on average every year there are 3.5 floods with the threat magnitude equal to or over the warning level 2, in which

36% are big floods or special bog floods. Flood season is determined from Oct. to Dec. or later, in Jan, however in some years it is earlier, in Sept., or even May, June,. Therefore, floods here include very early flood,, early flood, main season flood and late flood.

Table 2.3: *Intensity of Rainfall at Hue Station*

period	Annual mean	Month max	Month observed	Daily max	Date observed
1911-1920	2817	1568	11.1917	283	13.10.1916
1921-1930	3008	1241	11.1930	360	13.11.1930
1931-1940	2631	1166	10.1932	433	25.10.1939
1941-1950	3230	1547	10.1949	440	23.10.1949
1951-1960	2751	1078	10.1960	277	27.11.1960
1961-1970	2824	1792	10.1969	550	05.10.1969
1971-1980	2666	1564	10.1973	470	23.10.1973
1981-1990	2575	1527	10.1983	582	10.10.1981
1991-2000	3093	2452	11.1999	978	02.11.1999
2001-2006	2827	1526	11.2004	682	26.11.2004

Very early flood Flood often occurs in the end of April or early June; it is small, only at warning level I.

Early flood appears in July, Aug. with very low frequency, in Sept. with frequency of about 30%. Early flood is often small, with short duration, only 1–3 days.

Main season flood appears in Oct., Nov., and first half of Dec. during the time of strong activities of typhoon, tropical cyclone and tropical convergence zone in combination with the cold air mass that cause heavy rain on large area in the South of Northern Central Vietnam and the North of South Central. Main season flood has high peak and often is double floods.

Late flood appears by the end of Dec. early Jan, often has low intensity and small amplitude.

Flood on the Huong River and other rivers of Thua Thien Hue is bigger than flood on the basins in the North and South (Table 2.4). The biggest runoff module of Ta Trach River at Thuong Nhat station and Bo River at Co Bi station successively are 3,849m3/skm2 and 3,958m3/skm2

Table 2.4: *The biggest flood runoff characteristics in some basins*

River	Station	Province	Area of basin (km^2)	Biggest discharge (m^3/s)	Runoff module (m^3/skm^2)
Cai	Thanh My	Quang Nam	1.850	3,010	1.632
Thu Bon	Nong Son	Quang Nam	3.310	5,749	1.837
Ta Trach	Thuong Nhat	Thua Thien Hue	186	716	3.849
Bo	Co Bi	Thua Thien Hue	720	2,850	3.958

On Huong River, the record peak flood discharge in Hue in 1953 is 12500m3/s and 1999 is 14000m3/s; record water level at Kim Long is 5.81m, higher than the altitude of Hue city about 2.5m.

The duration of occurrence of a flood is often different between mountainous area and the plain. At Thuong Nhat Station (mountainous area), due to big slope of the catchment and slope of river bed, flood goes up very fast and goes down also very fast, lasting about 1–3 days. At Phu Oc Station (plain area), the slope of river bed is small, moreover it is affected strongly by the tide, so flood often lasts about 3–5 days.

Depending on the rainfall, rainfall intensity and river cross section, the flood amplitude is small about 3–5m, flood intensity about 1–2m/s in mountainous area and 0.5–1.0m in plain.

Figure 2.1: *Flood in Thua Thien Hue 2007*

It is noted that, according to data from 1996 to 2005, in Thua Thien Hue annually, there is a flood. On the Huong River and on the Bo River, on average, every year there are more or less 7 flood from level I upward, but there is not flood in May, June and July, and flood in Dec. is not so much as in Sept. (Table 2.5). Particularly in recent 10 years there have been no flood of grain fills, no late flood in Jan; but in every year there were flood over level 3 and particularly in 2007 there were 5 floods of this level.

Table 2.5: *Average number of flood on the Huong and Bo Rivers in 1996–2005*

Month	V	VI	VII	VIII	IX	X	XI	XII	Year
Huong	0.0	0.0	0.0	0.2	1.4	3.0	2.1	0.7	7.4
Bo	0.0	0.0	0.0	0.1	1.7	2.6	2.1	1.1	7.6

According to historical records, from 1801–1888 Hue Capital city and neighboring areas had to endure 40 big floods, with the following typical floods:

- The flood of 1811 inundated the Royal Palace at 3.36m, broke the main building of the Palace.

- Flood in 1818 inundated Hue City at 4.2m.

- The successive floods in two years 1841–1842 made 7000 houses collapsed, the city was heavily damaged, and many people died.

- The flood of Oct. 1844 killed more than 1000 people, 2000 houses were totally destroyed, the flag pole at the flag platform was broken, and Hue City was inundated at 4.2m.

To the 20-th century, Thua Thien Hue had been destroyed many times by floods, most noted are the following floods:

- The flood from Sept. 20–26, 1953 killed more than 500 people, 1290 houses washed away, 300 cattle died or washed away, 80% area of crop were completely lost.

The big flood from Oct. 15 to 20, 1975 caused big damages in life and property of the people.

- From Oct. 28 to Nov. 1, 1983, a big flood killed 252 people, 115 injured, 2015 houses collapsed and washed away, 1.027 schools collapsed, 160,537 cattle, 880,000 poultry died. Total losses were up to 1,761.82 bil. VND.

- The historical flood of Nov. 1999 killed 352 people, 21 missing, 99 injured, 25,056 houses washed away, 1,027 schools collapsed, 160,537 cattle died.

2.4 Flash flood and its impacts

Flash flood in mountainous area often happens in small basins due to intensive rainfall in a short time. The flood water concentrates very fast, and has great content of solid matters, big kinetic energy and strong washing force that have capability of leveling all obstacles on its way.

According to recent investigations and surveys, in Thua Thien Hue Province there were 48 points in which flash flood happened with density of 0.01 points/km2, this value is very high in our country. Actually, the flash flood density was higher, but most of mountainous areas have no inhabitants, as a result the phenomenon of flash flood was not fully recorded.

Flash flood in Thua Thien Hue includes obstructed flash flood, slope flash flood, mixed flash flood and rock mud flash flood.

In mountainous area, obstructed flash flood often happens in depressed area with densely populated people such as A Luoi, Nam Dong, Phu Loc and Huong Tra.

Slope flash flood often happens in small catchments such as mountainous areas. Water current from water catchments pours down the slope with very big velocity bringing with it a lot of wastes, sandy mud after the showers with very high intensity and lasted for hours on steep rivers or streams…

Slope flash flood has broken small spillways on streams, particularly the one close to the foot of La Hy Pass (Nam Dong) and Ro Ho Spillway in A Luoi Town.

Mixed flash flood is the combination of obstructed flash flood and slope flash flood often appears on short rivers and streams flowing into plain. Heavy rain existed many days on narrow and steep river valleys making the water rise high in mountainous area, then suddenly pours down narrow rivers with very great potential energy, overflowing the plain. This kind of flash flood has happened in Bang Lang –Minh Mạng Tomb (confluence of Ta Trach and Huu Trach Rivers), Lại Bang-Co Bi (Bo River), Duong Hoa (Ta Trach) and Huong Ho (Huong River) in the flood of 1999.

2.5 Landslide, erosion of river bank, seashore and impacts

On National Highway 1A, landslide often happens at Phuoc Thuong Pass, Phu Gia Pass and North Hai Van Pass.

At the foot of Phuoc Thuong Pass (km 901) in the flood of Nov. 1999, land slide happened on cut-slope from mountain peak of 70m high, 250m long; a volume of nearly 10,000m3 rock soil filled up the railway tunnel. The collapse developed on the granite weathering crust.

At Hai Van Pass also in the flood of 1999, collapse happens on both cut-slope and filling-slope, washing away 70m of the road, and making a bridge of 15m long collapsed.

On the part of Ho Chi Minh Highway passing through Thua Thien Hue, landslide develops very strongly, especially on the section from A Roang to A Dot due to high mountains, deep dividing, and very thick weathering crust.

Landslide is extremely serious in the township of Phu Loc District.

Apart from landslide, in Thua Thien Hue there is also the erosion of river bank, mainly on big rivers of Huong, Bo and Truoi, the sea shores of Thuan An and Hai Duong...

After flooding, on most river banks in middle stream such as Xuoc Du (the main current of Huong River), Phong Son, Phong An, Huong Son (B River), appear many erosion points and flood plains, affecting hundreds of riparian households.

In recent years, flood with very high intensity in combination with spring tide eroded nearly 15,000m bank of the Huong River far to the land, in some places up to dozens of meters, taking away a lot of areas of the fertile riparian gardens and rice field. Especially erosion at Xuoc Du Groin in the flood of Nov. 1999 created many erosion holes, some of them are 30–50m wide, deeply into the border near the slope of river bank.

Huong River has a large crookedness while the current in flood season always has the tendency to find the shortest way, so apart from the bank erosion there is also the possibility of changing the current. Moreover, erosion often happens on the section of the Huong river from Tuan Confluence to Thuan An of 29km long with dense population along two sides, and flowing through Hue City, a world cultural heritage.

Being contrary to erosion of river bank is the silting of river mouth. By the end of 1994, the Tu Hien estuary was filled up, causing inundation on many rice fields at the side of lagoon and ecological changes in Cau Hai swamp.

Estimation by experts the impacts of the disasters on different area and sectors in Thua Thien Hue shown that main impacts would cause typhoon, sea level rise, flood, drought and salinity intrusion. And most effected are Agriculture, Aquaculture Forestry, Irrigation, Water Resources and water suply. Table 2.7, 2.8

Table 2.6: *Disaster and disaster's Impacts in Thua Thien Hue (cont.)*

		Sea level rise	Pre. change	Typhoon	River flow change	Land-slide	River bank, sea dyke erosion	Increase in tempera-ture	Flash flood	drought and salinity intrusion
Infrastructure	Transportation	-	+++	++	++	+++	-	-	++	+++
	Water drainage	++	+++	++	++	-	-	-	-	+
	Water supply	-	+++	++	++	-	-	++	++	+++
	Electricity	-	++	+++	-	++	-	++	-	++
	Telecommunications	-	++	+++	-	-	-	-	-	-
Sector	Agriculture	++	+	++	+++	-	++	++	-	++
	Forestry	++	-	++	++	+	-	++	++	++
	Irrigation	++	++	++	+++	-	-	++	+++	+++
	Aquaculture	+++	++	++	+++	-	+++	++	-	+++
	Biodiversity	+++	-	-	-	-	++	+++	-	+
	Water Resources	+++	+++	+	+++	-	-	++	++	++

+++: Strong impact
++ : Medium impact
+ :Low impact
- : Non-impact

Table 2.7. *Disaster and disaster's Impacts in Chan May – Lang Co SEZ*

Subject		Sea level rise	Pre. change	Typhoon	River flow change	Land-slide	River bank, sea dyke erosion	Increase in temperature	Flash flood	drought and salinity intrusion
Land use planning	harbor	+++	+	+++	-	++	-	-	-	+
	Coastal tourism area	+++	++	+++	+	-	++	-	-	-
	Economic-Trade area	+	++	+++	-	++	-	-	-	-
	Urban area	++	++	+++	++	-	++	-	-	-
	Lang Co town	++	++	+++	++	-	++	-	-	++
	Son Tra peninsula	+++	-	+++	-	+	-	+++	-	+
	Voi stream	-	++	+	++	++	-	-	++	++
	Hoi Dua, Hoi Mit	-	++	++	+++	++	-	-	+++	++
	Bu Lu Mangrove forest	+++	-	++	-	-	-	+++	-	++
	Chuoi flood plain	+++	-	+++	-	+	-	-	-	++

+++: Strong impact
++ : Medium impact
+ :Low impact
- : Non-impact

CHAPTER 3: OVERVIEW ON CLIMATE CHANGE ON THE WORLD, IN VIET NAM AND THUA THIEN HUE PROVINCE

3.1 Climate change on the world

In the process of formation and existence of the Earth, climate has been always in continuous changes. Whether in ancient geologic time or in contemporary historical time, climate always has different warm, cold, dry and wet periods...

In recent more than 100 years, from 1906 to 2005, the global average temperature has increased by 0.740C with the speed of increasing in recent 50 years double the one of previous 50 years. Two years with the ever highest global average temperature are 1998 and 2005.

Also in the last 100 years, rainfall has had the increasing tendency in the North of latitude 300 N, but decreasing tendency in many tropical area; drought appeared more often in tropical and sub-tropical area; activity of tropical cyclone, especially strong typhoon have increased and more and more typhoons with abnormal trajectories.

In the 20th century, together with the rise in temperature, there was the reduction of ice mass on global scale. The observations in 1978 up to now have given the results that the average annual ice mass in the Arctic Ocean decreased by 2.7% per decade. Ice on mountainous areas on both hemispheres also melts with significant volume. In the Arctic, the range of ice cover dropped by 7% in comparison to 1990.

There are many changes in mechanism of atmospheric circulation on large scale on both continents and oceans, leading to the rise in number and intensity of phenomena El Nino as well as La Nina.

Particularly the sea level rose by 1.8mm every year during the period 1961–2000 and up to 3.1mm during 1993–2003.

From the end of 1980s, many international organizations had raised their voices to warn about climate change, especially the temperature increasing and sea level rise on global scale. That is why the United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992 in Brazil with the aim to stabilize the concentrations of greenhouse gases (GHGs) in the atmosphere to prevent the dangerous anthropogenic interventions into the climate system.

The cause of global climate change is the incessant increase of the anthropogenic GHGs emitted from 2 main sources of using fossil fuels and deforestation. The GHGs emissions are basically decided by population growth, economic growth and energy use. Therefore the Third Assessment Report (TAR) and Fourth Assessment Report (FAR) of the Intergovernmental Panel on Climate Change (IPCC) has presented scenarios on GHGs emissions as well as scenarios on the rises of temperature and sea level for the time landmarks in the 21st century. IPCC has built a Special Report on Emission Scenarios (SRES), which presented the following 4 “Storyline Scenarios” and 6 scenarios:

- “Storyline Scenarios”A1: storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies.

Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income..

- The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system.

+ Scenario A1F: mainly fossil fuel

+ Scenario A1T: mainly non-fossil fuel

+ Scenario A1B: Balance of energy sources

- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

- The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

- The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Table 3.1: *Amount of C emission (billion tons) and CO_2 concentration in the atmosphere (ppb) in different scenarios*

Scenario	**Amount of C emission**					**CO_2 concentration**	
	2020	2040	2060	2080	2100	2050	2100
A1B	12.2	15.0	15.1	14.9	13.4	510	730
A1T	10.0	12.4	11.8	8.0	5.0	500	580
A1F1	12.2	19.5	26.0	29.5	29.1	610	970
A2	12.1	15.7	19.2	23.5	30.0	590	850
B1	8.0	8.2	8.0	7.0	5.2	470	550
B2	8.2	10.6	11.9	12.3	13.2	480	620
IS92A	11.5	13.0	15.0	16.9	20.2	510	740

IPCC also mentioned that, if all C generated from land-use change is recovered in the soil ecosphere, GHGs concentrations in the atmosphere would decrease down to from 40 to 70 ppm.

Table 3.2: *Spans of temperature rise in accordance with the rise of CO_2 content projection for 2100.*

IPCC Scenario	**Compared to mean temperature of period 1980 – 1999 (^{0}C)**	**Compared to temperature of pre-industry period**
Levels of concentrations in 2000	0.6 (0.3 – 0.9)	1.1
Scenario B1	1.8 (1.1 – 2.9)	2.3
Scenario A1T	2.4 (1.4 – 3.8)	2.9
Scenario B2	2.4 (1.4 – 3.8)	2.9
Scenario A1B	2.8 (1.7 – 4.4)	3.3

Scenario A2	3.4 (2.0 – 5.4)	3.9
Scenario A1F1	4.0 (2.4 – 6.4)	4.5

Apart from building scientific basis of climate change, the reports of IPCC also bring forth the assessments on climate change impacts and propose strategy to respond to climate change. According to the fourth report, there has been enough evidence on climate change impacts on all continents and almost all the oceans, natural and continental ecosystems that typically were:

- The time of growth season of cultivated crop in high latitudes came earlier;

- The season of growth of cultivated crop in Sahel was shortened due to the weather has become warmer and drier;

- Many low lands disappeared and mangroves were seriously damaged due to flooding in coastal zone;

- Epidemics developed in many areas, especially in low latitudes;

Also in the fourth report, there would be many climate change impacts in almost all fields in the 21st century:

- In the middle of the 21st century, the runoffs of rivers would increase by 10–40% in high latitudes and wet tropical area and decrease by 10–30% in middle latitudes and dry tropical area.

- Around 20–30% cultivated crop and livestock would pose to more risks due to temperature rise.

- The productivity of crop would have minor increase in high and medium latitudes but decrease in low latitudes.

- Flood and erosion would increase obviously in coastal zones.

- The balance between profit and expenditure of many industrial branches would tend toward negative effect.

- The proportion of death due to typhoon, flood and drought would raise and proportion of sickness and diseases would be higher.

With the above-mentioned reasons, IPCC recommends to carry out climate change impacts assessment for all fields, sectors and territories, particularly 5 following fields: Water, ecosystems, food, coastal zones and health.

At present, all countries over the world have paid special attention to the development of strategies and setting up solutions to respond to climate change. Strategies to respond to climate change include two main parts: mitigation of climate change and adaptation to climate change.

3.2 Climate change in Viet Nam

Viet Nam has the tropical monsoon climate of a peninsular in Southeast Asia, stretching over 15 latitudes, fully lying inside the tropics of northern hemisphere and is deeply influenced by the West Pacific and the East Sea.

The atmospheric circulation in Viet Nam is the combination of the Northeast Asia monsoon and the South Asia monsoon. Under the impacts of the Northeast Asia monsoon, every year there are 26 cold front intrusions into the North.

From the West Pacific and the East Sea, in average every year there are more than 8 tropical cyclones, including typhoons and tropical depressions landing on coastal areas.

3.2.1 Changes of some typical climate elements

3.2.1.1 Changes of tropical cyclone frequency

During 40 years (1961- 2000), changes of tropical cyclones on the East Sea have the following noted points:

(1) Tropical cyclones on the East Sea have the standard deviation of 2.93 and variance of 27%

(2) There were 15 years (37.5%) in which tropical cyclones are more than average and 16 years (40%) in which tropical cyclones are less than average.

(3) Tropical cyclones have the biggest number in 1981 (20) and smallest in 1969 (5).

3.2.1.2 Changes of temperature

Yearly changes of average temperature have some following characteristics:

1) Changes of average temperature are relatively much in the most in winter months (Dec-Feb.) and relatively little in summer months, the least in months of mid summer (Jun-Aug.)

2) Changes of average temperature in May and Oct., typical for the transition period between seasons, not so much as in Jan. and so little as in July

3) Changes of annual average temperature are less than any months, including mid-summer.

3.2.1.3 Changes in rainfall

Changes in rainfall have some following characteristics:

1) On the same location, standard deviation of annual rainfall is bigger than the monthly one and of the month with much rainfall is bigger than the one with little rainfall. On the contrary, variance of annual rainfall is smaller than the one of monthly rainfall and of months in rainy season smaller than in dry season

2) Rainy season also varies strongly from year to year in starting time, the peak month as well as the ending time. In general, rainy season can fluctuate in 3–4 months or more, depending on rainfall variation of the area.

3.2.2 Tendency of climate change in Viet Nam

3.2.2.1 Overview on tendency of climate change in the region

Climate change has a clear regional character. Related to climate change in Viet Nam are some characteristics of climate change in tropical area and the Asia – Pacific Ocean.

In general, tropical area is not the place of the strongest increase in temperature in present-day global warming tendency. However, on the tropical sea, rainfall and also evaporation have obviously increasing tendency more than in other areas.

In the tropical Pacific Ocean, climate change manifests in two main characteristics:

(1) Average temperature increases, but not so much as in other areas.

(2) Rainfall increases in many places, but decreases in some other places.

3.2.2.2 Trend of climate change in Viet Nam

By analyzing the Standard Deviation (SD) and Variability Rate (VR) of the main parameters, we can assess magnitude and intensity of the changes in every stations and locations. By processing the graphs of detailed variability by time, moving average and linear trend line, we can find the trends and characteristics of changes by time. In the tables below, we can see some qualitative and quantitative characteristics of temperature and rainfall changes at A Luoi. The same change characteristics have been observed at Nam Dong and Hue stations in different time periods.

Table 3.3: *Characteristics of temperature changes (^0C) at A Luoi station*
Time scale: 1974-2004

Categories	January	April	July	October	Annual
Average	17.4	22.9	24.9	21.5	21.9
Standard Deviation	1.05	0.78	0.55	0.74	0.35

Table 3.4: *Characteristics of rainfall changes (mm) at A Luoi station*
Time scale: 1974-2004

Categories	Jan_Mar	Apr_May	Jun_Jul	Aug_Dec	Annual
Average	170.5	396.1	357.6	2496.0	3464.1
Standard Deviation	84.0	106.1	165.4	876.4	988.5
Variability Rate (%)	49.3	26.8	46.2	35.1	28.5

Trends and tendency of changes:

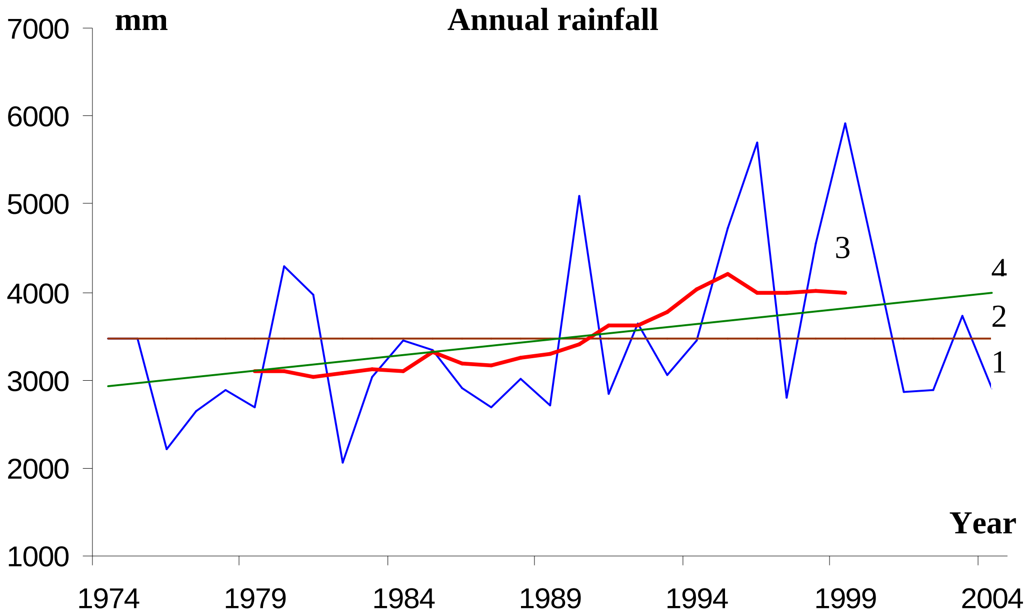

Figure 3.1: *Variability (1), climatological average (2), moving average (time step - 11 year) (3) and linear trend (4) of annual rainfall at A Luoi station.*

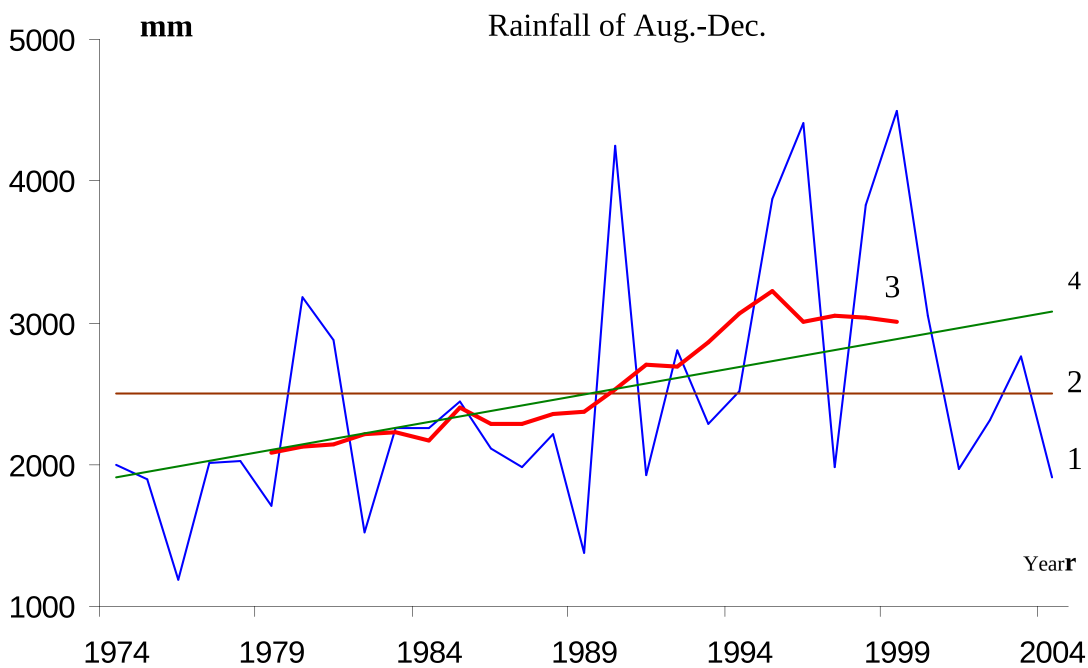

Figure 3.2 - *Variability (1), climatological average (2), moving average (time step - 11 year) (3) and linear trend (4) of August-December rainfall at A Luoi station*

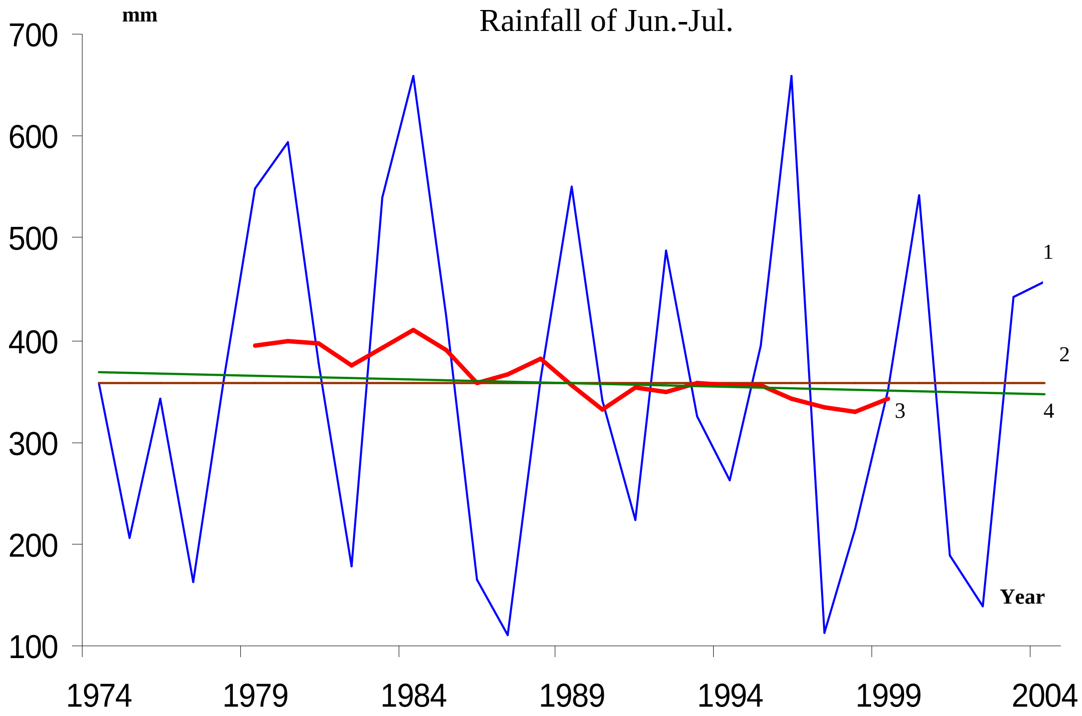

Figure 3.3: *Variability (1), climatological average (2), moving average (time step - 11 year) (3) and linear trend (4) of June-July rainfall at A Luoi station.*

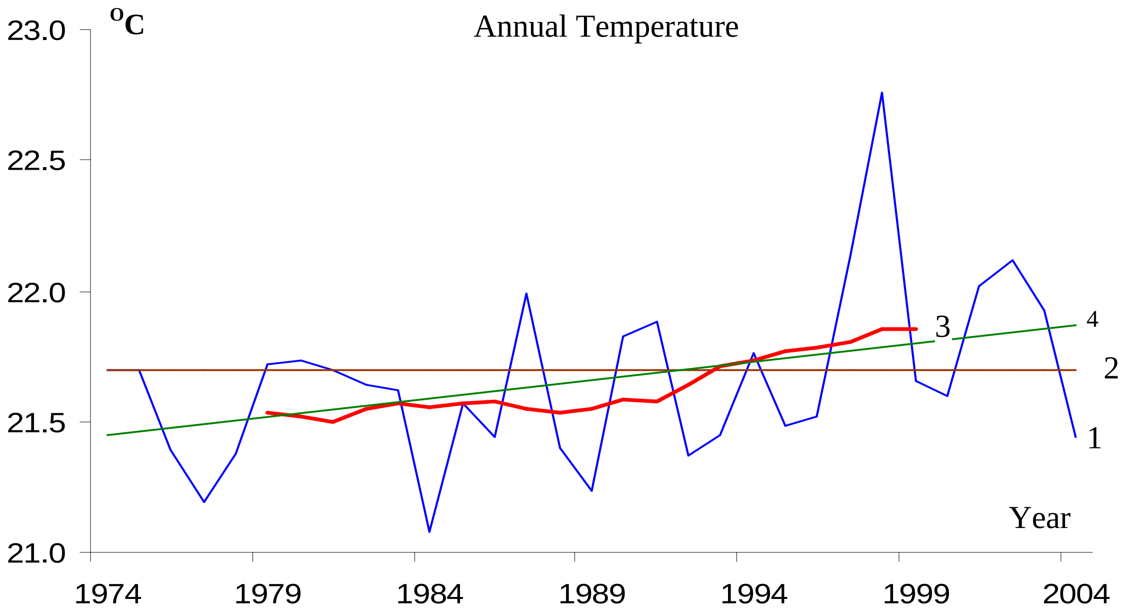

Figure 3.4: *Variability (1), climatological average (2), moving average (time step - 11 years) (3) and linear trend (4) of annual average temperature at A Luoi station.*

In general, Thua Thien Hue’s climate has been significantly influenced by monsoon with subsequent characteristics, so theoretically it could be divided into two main seasons: dry and rainy (or hotter and cooler) seasons. However, beside the influences of cold fronts from the North and North-East monsoon which may start from April-May, creating first “summer” rainy period, there is also dry and hot South-West monsoon from Cambodia and Laos, going through Truong Son high mountains and creating “interruption” of summer rains. This period of year (Jun-July) is usually dry with low rainfall, but then, from August to December, the “real rainy season” will start rapidly with very high rainfall and continuing precipitation.

By the above reasons, we study the rainfall of 4 different periods of the year: January-March; April-May; June-July and August-December and respectively, the temperature of January, April, July and October, typically for each period. The July is typical for hot season, the January is typical for cooler season, and the April and October are typical for transitional seasons or “interchange”.

Annual rainfall of A Luoi and Nam Dong stations are very high in absolute value (about 3500 mm in average and up to 6000 mm in the peak years), and have significantly increased in the period from 1974-2004 for almost 800mm and 600mm respectively

The biggest change of rainfall with highest increase is occurring in rainy season (August to December), which contribute very high percentage to the annual rainfall.

June-July’s rainfall at both stations has obvious trend to decrease, which indicate high risk of drought for important growth period of agricultural plants and crops, and water shortage for electricity generation, higher municipal needs at the hottest period of the year.

Temperature of all typical months and mean annual temperature at A Luoi and Nam Dong stations in the studied period (1974-2004) have trend to increase.

Changes of typhoon

In this paper, changes of typhoon frequency and season are analyzed following the data in the report “Natural disasters in Thua Thien Hue” which the Center for Hydro-Meteorological Forecasting of Thua Thien Hue Province” carried out and published in 2006.

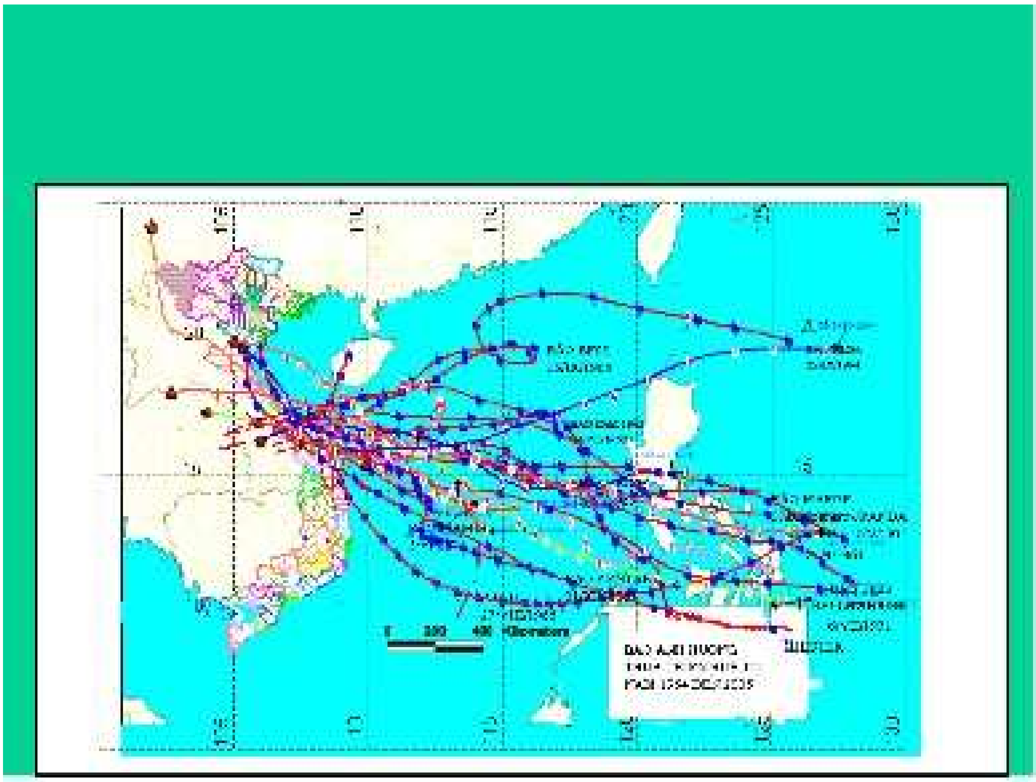

Figure 3.5: *Typhoon impact to Thua Thien Hue*

From 1952 to 2006, Thua Thien Hue had been affected by 35 typhoons; in average every year has 0.63 typhoons. Typhoon season, which is understood as the time with no less 0.05 typhoons/month is from May to November.

During the above 55 years, changes of typhoon frequency and season have the following noted points:

(1) Annual typhoon frequency has the standard deviation of 0.63 and relative variance of 99%. The standard deviation of monthly typhoon frequency is very low, only from 0.11 to 0.39, but relative variance is very high, approximately 200% or more.

(2) For each decade, typhoon has the biggest number in 1971–1980 and the smallest in 1991–2000. In the first half of 2001–2010 there were only 2-3 typhoons in Oct. and Nov., the second half of typhoon season.

3.2.3 Scenarios of climate change in Viet Nam

Climate change scenarios in Viet Nam which presented in initial Communication have been built for three main elements: temperature, rainfall, sea level and the main time landmark are 2010, 2050 and 2070.

The simulations of temperature, rainfall and sea level changes in various regions are shown in table 3.5 below:

Table 3.5: *Climate change simulations in Viet Nam*

Factors	Region	Season	2010	2050	2070
Temperature is increasing (^0C)	Northwest, Northern of North		0.5	1.8	2.5
	Northern plain		0.3	1.1	1.5
	North of Central		0.3	1.1	1.5
	Middle of Central		0.3	1.1	1.5
	South of Central		0.3	1.1	1.5
	High land		0.5	1.8	2.5
	South		0.3	1.1	1.5
Rainfall amount is increasing (+) or decreasing (-) (%)	Northwest, Northern of North	Rainy	0	0-+5	0-+5
		Dry	0	-5-+5	-5-+5
	Northern plain	Rainy	0	0-+5	0-+5
		Dry	0	-5-+5	-5-+5
	North of Central	Rainy	0	0-+10	0-+10
		Dry	0	0-+5	0-+5
	Middle of Central	Rainy	0	0-+10	0-+10
		Dry	0	0-+5	0-+5
	Northern part of South Central	Rainy	0	0-+10	0-+10
		Dry	0	0-+5	0-+5
	Southern part of South Central	Rainy	0	0-+5	0-+5
		Dry	0	-5-+5	-5-+5
	Central High land	Rainy	0	0-+5	0-+5
		Dry	0	-5-+5	-5-+5
	South	Rainy	0	0-+5	0-+5
		Dry	0	-5-+5	-5-+5
Sea level rise (cm)	All coastal line	-	9	33	45

3.2.4 Future climate change in Thua Thien Hue:

3.2.4.1 Methodology

The methodology applied in this study is based on the Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment published by IPCC (Carter et al. 1999).The main steps in the study shown in

Basic sources of input, information, and marginal data are:

(i) Results of global and regional (South-East Asia) climate scenarios using Global Circulation Model (GCM) and Ocean-Atmospheric Global Circulation Model (OAGCM);

(ii) IPCC's global emission scenarios (according to the guidance of the Third Assessment Report of IPCC for regional scenarios) and regional climate scenarios for South-East Asia;

(iii) Trend observed from monitoring meteorological data for the last 30-40 year in Vietnam and Thua Thien Hue province;

(iv) Experts' opinions, conclusions and related literatures, including influences of regional factors and ENSO on climate of Vietnam;

(v) Observed data on sea levels at stations and analysis from Marine Hydro-Meteorological Center.

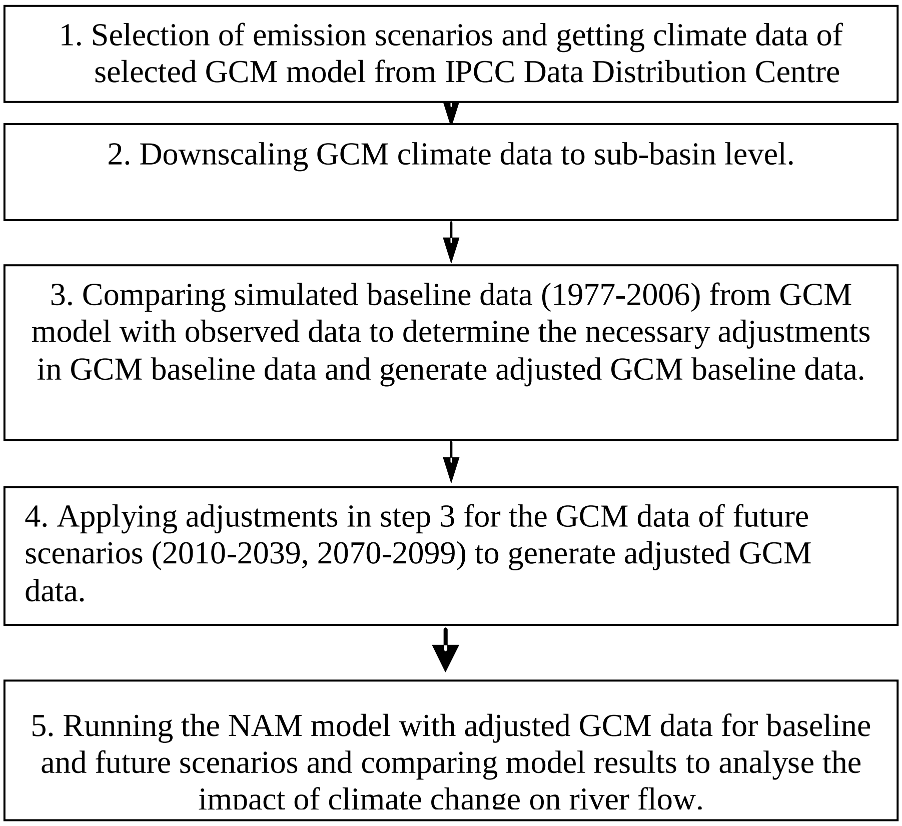

Figure 3.6: *Process of climate change study*

3.2.4.2 *Changes in temperature and rainfall*

There are 6 different emission options (2 High-, 2 Medium- and 2 Low-emission) for Thua Thien Hue province selected. Tables from 3.7 to 3.12 present the changes of rainfall and temperature in TT Hue over the period 2010 – 2100 with different emission scenarios in comparison to 1990. Figure 3.7 shows the downscaling results of temperature and rainfall for Huong river basin with the scenario B2.

However, in this research we only focus on two of the Emissions Scenarios B2 and A1F1 of the IPCC Special Report (IPCC, 2001) on Emissions Scenarios (SRES).

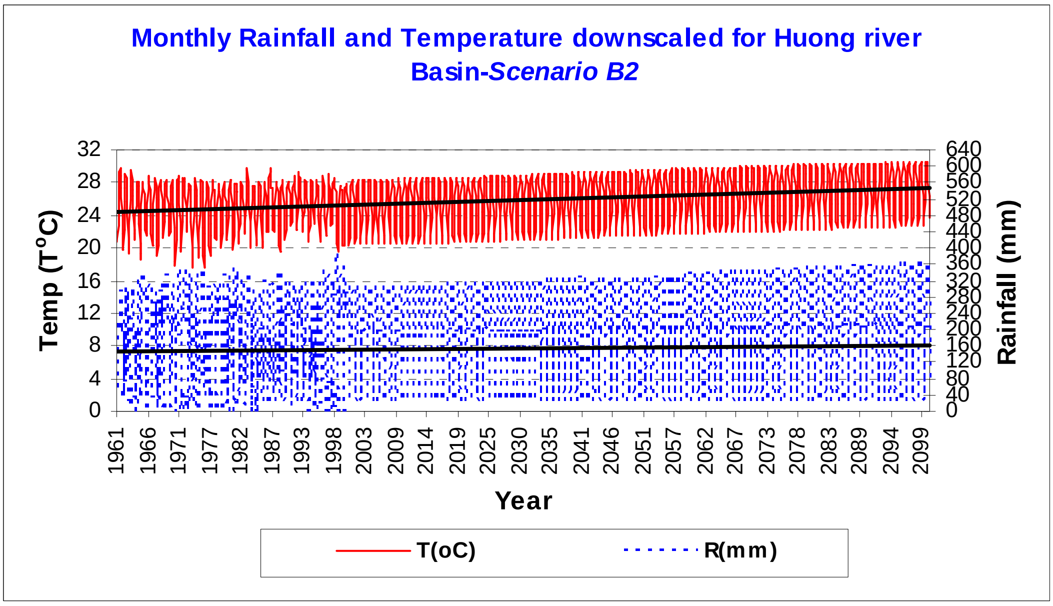

Figure 3.7: *Monthly Rainfall and Temperature downscaled for Huong river basin scenario B*

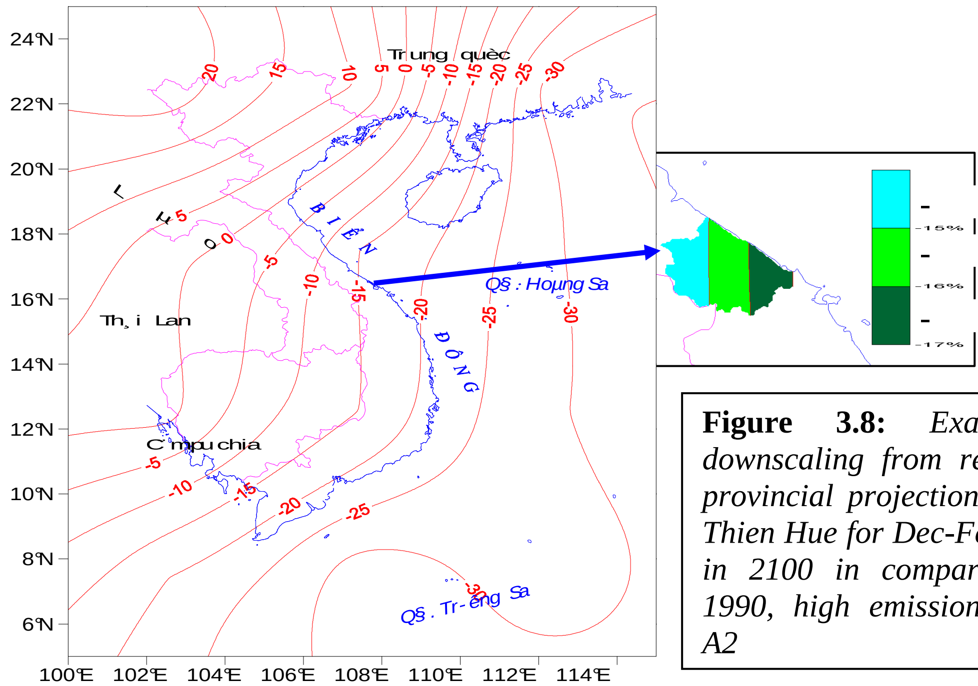

Figure 3.8: *Example of downscaling from regional to provincial projection for Thua Thien Hue for Dec-Feb rainfall in 2100 in comparison with 1990, high emission scenario A2*

Table 3.6: *Increase in annual and seasonal temperature (^{o}C) in TT Hue by decades of 2010-2100, comparing with 1990, respectively to 2 High emission scenarios (A1FI and A2)*

Scenario	Period	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
A1FI	Year	0.2	0.3	0.6	0.9	1.4	2.0	2.6	3.1	3.5	3.9
	Dec-Feb	0.2	0.3	0.6	0.9	1.5	2.1	2.7	3.2	3.7	4.0
	Mar-May	0.2	0.4	0.7	1.1	1.7	2.4	3.1	3.7	4.3	4.7
	Jun-Aug	0.2	0.3	0.6	0.9	1.5	2.1	2.7	3.2	3.7	4.1
	Sep-Nov	0.2	0.3	0.6	0.9	1.4	2.0	2.6	3.2	3.6	4.0
A2	Year	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.6	2.1	2.6
	Dec-Feb	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	2.0	2.5
	Mar-May	0.2	0.4	0.5	0.7	0.9	1.2	1.4	1.8	2.4	3.0
	Jun-Aug	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.6	2.1	2.6
	Sep-Nov	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	2.0	2.5

Table 3.7: *Change in annual and seasonal rainfall (%) in TT Hue by decades of 2010-2100, comparing with 1990, respectively to 2 High emission scenarios (A1FI and A2)*

Scenario	Period	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
A1FI	Year	0.5	0.9	1.5	2.5	4.0	5.7	7.3	8.7	10.0	11.0
	Dec-Feb	-1.0	-2.0	-3.3	-5.4	-8.5	-12.0	-15.4	-18.5	-21.2	-23.4
	Mar-May	0.4	0.8	1.3	3.1	3.4	4.8	6.1	7.4	8.4	9.3
	Jun-Aug	0.7	1.1	2.2	3.6	5.6	8.0	10.3	12.3	14.2	15.6
	Sep-Nov	1.1	2.1	3.5	5.7	8.9	12.7	16.3	19.6	22.4	24.7
A2	Year	0.4	0.9	1.2	1.7	2.2	2.7	3.3	4.2	5.6	7.0
	Dec-Feb	-0.9	-1.8	-2.4	-3.6	-4.6	-5.7	-6.9	-8.9	-11.8	-14.8
	Mar-May	0.4	0.7	1.0	1.4	1.8	2.3	2.8	3.6	4.7	5.9
	Jun-Aug	0.6	1.2	1.6	2.4	3.1	3.8	4.6	6.0	7.9	9.8
	Sep-Nov	1.0	1.9	2.6	3.8	4.9	6.1	7.3	9.4	12.5	15.6

Table 3.8: *Change in annual and seasonal temperature (^{o}C) in TT Hue by decades of 2010-2100, comparing with 1990, respectively to 2 Medium emission scenarios (A1B and B2)*

Scenario	Period	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
A1B	Year	0.3	0.5	0.8	1.1	1.4	1.8	2.1	2.3	2.5	2.6
	Dec-Feb	0.3	0.5	0.7	1.1	1.4	1.7	2.0	2.2	2.4	2.5
	Mar-May	0.3	0.5	0.8	1.2	1.5	1.9	2.2	2.5	2.7	2.8
	Jun-Aug	0.3	0.5	0.8	1.1	1.4	1.7	2.0	2.2	2.4	2.5
	Sep-Nov	0.25	0.4	0.7	1.1	1.4	1.7	2.0	2.2	2.4	2.6
B2	Year	0.3	0.5	0.8	1.1	1.4	1.7	2.0	2.2	2.4	2.6
	Dec-Feb	0.3	0.5	0.8	1.1	1.4	1.6	1.9	2.1	2.3	2.5
	Mar-May	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.6	2.8
	Jun-Aug	0.3	0.5	0.8	1.1	1.4	1.7	1.9	2.1	2.3	2.5
	Sep-Nov	0.3	0.5	0.7	1.1	1.4	1.6	1.9	2.1	2.3	2.5

Table 3.9: *Change in annual and seasonal rainfall (%) in TT Hue by decades of 2010-2100, comparing with 1990, respectively to 2 Medium emission scenarios (A1B and B2)*

Scenario	**Period**	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
A1B	Year	0.7	1.2	2.0	3.0	3.7	4.6	5.5	6.1	6.5	7.0
	Dec-Feb	-0.8	-1.3	-2.2	-3.4	-4.3	-5.3	-6.1	-6.8	-7.5	-7.9
	Mar-May	-0.8	-1.8	-2.2	-3.3	-4.2	-5.3	-6.2	-6.9	-7.4	-7.9
	Jun-Aug	1.0	1.7	2.7	4.0	5.0	6.2	7.2	8.0	8.7	9.3
	Sep-Nov	1.3	2.2	3.7	5.3	6.8	8.4	9.8	11.0	11.9	12.7
B2	Year	0.8	1.4	2.1	2.9	3.7	4.5	5.2	5.8	6.3	6.8
	Dec-Feb	-1.4	-1.5	-2.3	-3.3	-4.2	-5.0	-5.9	-6.6	-7.6	-7.8
	Mar-May	-0.9	-1.5	-1.8	-3.3	-4.2	-5.0	-5.9	-6.6	-7.7	-7.8
	Jun-Aug	1.0	1.8	2.7	3.8	4.7	5.9	6.9	7.7	8.4	9.1
	Sep-Nov	1.8	2.4	3.7	5.2	6.7	8.1	9.8	10.5	11.4	12.3

Table 3.10: *Change in annual and seasonal temperature (^oC) in TT Hue by decades of 2010-2100, comparing with 1990, respectively to 2 Low emission scenarios (A1T and B1)*

Scenario	**Period**	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
A1T	Year	0.3	0.6	0.9	1.2	1.5	1.7	1.9	2.0	2.1	2.2
	Dec-Feb	0.4	0.6	0.9	1.2	1.5	1.7	1.9	2.0	2.1	2.2
	Mar-May	0.3	0.6	0.9	1.2	1.4	1.7	1.9	2.0	2.0	2.1
	Jun-Aug	0.3	0.6	0.9	1.2	1.4	1.7	1.9	2.0	2.0	2.1
	Sep-Nov	0.4	0.6	0.9	1.2	1.5	1.7	1.9	2.0	2.1	2.2
B1	Year	0.3	0.5	0.7	1.0	1.3	1.5	1.7	1.9	2.0	2.1
	Dec-Feb	0.3	0.5	0.6	0.9	1.2	1.5	1.7	1.9	2.0	2.1
	Mar-May	0.3	0.5	0.7	1.0	1.3	1.5	1.7	1.9	2.0	2.1
	Jun-Aug	0.3	0.5	0.7	1.0	1.3	1.5	1.7	1.9	2.0	2.1
	Sep-Nov	0.3	0.5	0.6	0.9	1.2	1.5	1.7	1.9	2.0	2.1

Table 3.11: *Change in annual and seasonal rainfall (%) in TT Hue by decades of 2010-2100, comparing with 1990, respectively to 2 Low emission scenarios (A1T and B1)*

Scenario	**Period**	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
A1T	Year	1.0	1.7	2.4	3.3	4.1	4.8	5.4	5.8	6.0	6.1
	Dec-Feb	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5	-0.5	-0.6
	Mar-May	0.8	1.4	2.0	2.8	3.5	4.1	4.5	4.8	5.0	5.2
	Jun-Aug	1.1	2.0	2.9	3.9	4.9	5.7	6.3	6.8	7.1	7.2
	Sep-Nov	1.3	2.2	3.2	4.3	5.4	6.3	7.0	7.5	7.8	8.0
B1	Year	0.8	1.2	1.8	2.6	3.5	4.2	4.8	5.2	5.5	5.7
	Dec-Feb	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5	-0.5	-0.6
	Mar-May	0.7	1.0	1.5	2.3	3.0	3.6	4.1	4.4	4.6	4.8

	Jun-Aug	1.0	1.5	2.1	3.2	4.3	5.1	5.8	6.2	6.5	6.7
	Sep-Nov	1.0	1.6	2.3	3.5	4.7	5.6	6.3	6.8	7.2	7.4

3.2.4.3 Sea level rise

The sea level rise scenarios of Thua Thien Hue can be estimated by taking average values of Hon Dau Station, representing the coastal zone of North Viet Nam and Vung Tau Station, representing the coastal zone in the South of Viet Nam (Table 3.12)

Table 3.12: *Sea level rise in decades of century 21 in Hon Dau, Vung Tau and Thua Thien Hue (cm)*

Station	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Hon Dau	13.4	18.0	22.6	27.2	31.8	36.4	41.0	45.6	50.2	54.8
Vung Tau	10.7	16.2	21.7	27.2	32.7	38.2	43.7	49.2	54.7	60.2
Thua Thien Hue	12.0	17.0	22.0	27.0	32.0	37.0	42.0	47.0	52.0	57.0

With almost the same trend as in all over country, at the end of this century, in case of best estimation, the annual mean temperature would increase for 2.5-2.60C, but the increase is more significant in January and February (2.6-2.70C) then in hot months June and July (2.4-2.50C)

Obviously that in the high emission case (A1FI), the temperature would increase most: 3.90C, and in the Mar-May period even up to 4.7oC. Such a high temperature increase itself may cause very serious consequences for socio-economic and eco-systems, especially for people health, but in combination with subsequent more extreme events (droughts, floods, storms etc.) it may lead to catastrophy in the Thua Thien Hue province.

The best estimation’s annual rainfall of Thua Thien Hue is also increase for about 7%, but in dry season, it would decrease down to 10-15% (February to May). In the other hand, it would increase significantly in rainy season up to 10-24% (September to November). Rainfall in August – the first month of rainy season - is increased much less (2.5-3%).

In “worst” case of high emission (A1FI), the rainfall of rainy season would increase until 25%, but the first dry months Dec-Feb decrease to -23%. The interesting fact is that the rainfall of dry season’s month (Dec-Feb and Mar-May) decrease, which may cause very severe droughts. At that case, the worst thing for socio-economic and eco- systems in Thua Thien Hue province is not only flood or typhoon but the adverse droughts too.

The sea level rise in Thua Thien Hue would be about 57 cm in 2100 (with certain uncertainty as explained earlier), much less than in Northern and Southern part, but still have to be taken into account.

In general, those results show that the very high rainfall which concentrates in some rainy months would increase the already high flood risk of this area, with all the adverse consequences, unless the comprehensive complex adaptation measures would be implemented.

However, the dry season would be longer and more severe, which would increase risk of droughts. The longer, severe droughts may adversely impact the energy generation in number of hydropower plants (under construction now or will be built soon) in Huong and other river of Thua Thien Hue, may threaten the municipal water supply for Hue city, irrigation for agriculture, cause fresh water shortage for down stream socio-economical and ecological systems. The salinizations of surface and ground water and soil at coastal areas may adversely impact the agriculture, aquaculture and eco-tourism, as well as the unique ecosystems of wetlands, Tam Giang - Cau Hai lagoons.

We can see that both the flood and the drought risk of future climate change impacts is very high for Thua Thien Hue.

3.2.4.4 Estimation of the potential evaporation in Huong river basin

In this study, the Thornthwaite's formula is applied to estimate ETo in order to simplify the calculation.

Applying Thornthwaite's formula to calculate monthly ETo for baseline, 2020 – 2049 and 2071 – 2100 scenarios at A Luoi and Hue stations. Then, gage weights calculated by Thiessen method and ETo values at meteorological stations, ETo for the stations and lateral sub-basins can be estimated. Figure 3.9 and Tables 3.13, 3.14 shown the computational results of monthly average ETo over periods.

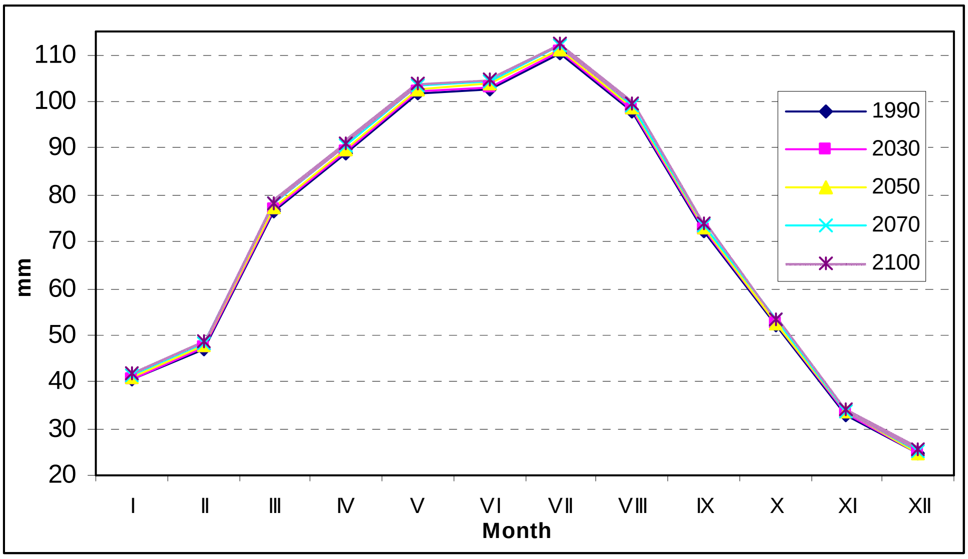

Figure 3.9: *Change in evaporation in different years at Ta Trach station*

Table 3.13: *Monthly potential evaporation (ETo) of sub-basins in 1990 (unit* ***mm****)*

Month	A Luoi	Ta Trach	Hue (LATERAL)	Huu Trach	Bo
I	38.2	40.5	46.9	41.6	39.8
II	44.2	47.1	50.6	47.5	45.4
III	67.1	76.4	74.4	74.7	68.4
IV	75.0	88.9	94.6	88.2	78.5
V	82.7	101.7	124.1	103.9	90.2
VI	83.7	102.7	127.2	105.4	91.5
VII	92.4	110.1	137.1	113.6	100.5
VIII	81.4	97.7	120.5	100.4	88.5
IX	57.6	72.3	88.7	73.8	63.2
X	46.0	52.1	66.6	54.4	49.7
XI	28.4	33.0	46.5	35.3	31.6
XII	24.5	24.5	38.5	27.6	27.0
Sum	721.3	846.8	1015.9	866.4	774.3

Table 3.14: *Monthly potential evaporation (ETo) of sub-basins in 2100 (unit mm)*

Month	A Luoi	Ta Trach	Hue (LATERAL)	Huu Trach	Bo
I	39.6	41.9	48.3	43.0	41.2
II	45.7	48.6	52.0	48.9	46.9
III	69.0	78.4	76.2	76.6	70.3
IV	76.9	90.9	96.6	90.2	80.4
V	84.6	103.8	126.4	106.1	92.2
VI	85.6	104.7	129.5	107.5	93.5
VII	94.5	112.4	139.5	115.9	102.6
VIII	83.3	99.7	122.7	102.5	90.4
IX	59.1	74.0	90.5	75.5	64.8
X	47.4	53.5	68.1	55.8	51.1

XI	29.4	34.1	47.7	36.4	32.7
XII	25.5	25.5	39.6	28.6	28.1
Sum	740.6	867.5	1037.2	887.0	794.0

3.2.5 Conclusion

In Thua Thien Hue's climate has been significantly influenced by monsoon with subsequent characteristics, so it divided into two main seasons: dry and rainy seasons

The biggest change of rainfall with highest increase is occurring in rainy season (August to December), which contribute very high percentage to the annual rainfall. Meanwhile June-July's rainfall has obvious trend to decrease, which indicate high risk of drought.

Temperature of all typical months and mean annual temperature in the studied period (1974-2004) have trend to increase.

In case of best estimation of projection, the annual mean temperature would increase for 2.5-2.60C, but the increase is more significant in January and February (2.6-2.70C) then in hot months June and July (2.4-2.50C)

Obviously that in the high emission case (A1FI), the temperature would increase most: 3.90C, and in the Mar-May period even up to 4.7oC to year 2100.

The best estimation's annual rainfall of Thua Thien Hue is also increase for about 7%, but in dry season, it would decrease down to 10-15% (February to May). In the other hand, it would increase significantly in rainy season up to 10-24% (September to November).

In "worst" case of high emission (A1FI), the rainfall of rainy season would increase until 25%, but the first dry months Dec-Feb decrease to -23%. The interesting fact is that the rainfall of dry season's month (Dec-Feb and Mar-May) decrease, which may cause very severe droughts.

The sea level rise in Thua Thien Hue would be about 57 cm in 2100 (with certain uncertainty as explained earlier), much less than in Northern and Southern part, but still have to be taken into account.

Due to increasing of temperature, the potential evaporation will increase respectively.

In general, those results show that the very high rainfall which concentrates in some rainy months would increase the already high flood risk of this area, with all the adverse consequences, unless the comprehensive complex adaptation measures would be implemented.

The dry season would be longer and more severe, which would increase risk of droughts. The longer, severe droughts may adversely impact the energy generation in number of hydropower plants (under construction now or will be built soon) in Huong and other river of Thua Thien Hue, may threaten the municipal water supply for Hue city, irrigation for agriculture, cause fresh water shortage for down stream socio-economical and ecological systems. The salinizations of surface and ground water and soil at coastal areas may adversely impact the agriculture, aquaculture and eco-tourism, as well as the unique ecosystems of wetlands, Tam Giang Cau Hai lagoons.

We can see that both the flood and the drought risk of future climate change impacts are very high for Thua Thien Hue.

CHAPTER 4: CLIMATE CHANGE IMPACTS IN THUA THIEN HUE

4.1 Introduction

4.1.1 Impacts of global warming and climate change

Increasing temperature has potential impacts on natural ecosystems. It would cause shifts in thermo-border of continental ecosystems and fresh water ecosystems as well as shifts in flora and fauna structure in certain regions. Degradation of biodiversity would accelerate due to loss of some temperate and sub-tropical species.

For agricultural production, cropping pattern and livestock may be changed in some regions, e.g. winter crop would be shortened or even no longer exist, whereas the main crop would prolong. Temperature rise with higher variability (both maximum and minimum temperatures) will combine with other climatic extremes and natural disasters to induce pestilent insects and diseases to wide spread. Consequently, agricultural production and food security would be seriously threatened.

High temperature and humidity would elevate pressures on human health, especially for old people and children, and cause diseases, particularly tropical and infectious diseases by favouring growing condition of bacteria, insects and diseases vectors.

Temperature rise would also badly affect such sectors as energy, transportation, industry, construction, tourism, trade, etc. due to the fact that higher cost would be spent for cooling, ventilation, and maintenance.

4.1.2 Impacts of climatic extremes

The increase of climatic extremes in both frequency and intensity due to climate change is a frequent risks, both short-term and long-term, to all sectors and communities. Storms, floods, droughts, heavy rains, and high temperature are annual disaster in province, causing large damages for production and life.

Climate change would make those natural disasters much more fierce, even become catastrophes, posing risks to socio-economic development and clear up achievements of many years of development, including achievements of millennium development goals. Thua Thien Hue is expected to suffer biggest impacts of those extremes.

4.2 Study on impacts of climate change on Water Resources in Thua Thien Hue

Water resources are put under additional risks due to ever increasing droughts. This will directly affect agriculture, water supply for rural and urban areas as well as electricity generation.

Water resource is one of the most vulnerable factors to the change of weather and climate, the variation of these phenomena nearly impacts directly on water resources. Some recent research show that global climate change (consequence of the accumulation of greenhouse air in the atmosphere) will influence characteristics of flow including total flow volume, frequency of the extreme events (drought and flood), seasonal regime, salinity intrusion and water quality in the ongoing decades. This leads to have the plans and measures to adapt effectively with the climate change in which the determination of the impact of climate change on water resources has a very important role.

Huong River is a main source of water for agriculture, aquaculture, supply for industry and energy generation, municipal and civil use, for existence of aquatic and water related environment, ecosystems and wild life on the large area. The most of people living in the Huong River basin strongly depend on its water (hydrological) regime. In Huong River basin there is a unique ecological and economical site – Tam Giang – Cau Hai lagoons - the largest and most complicated lagoon system in Vietnam, which is very sensitive to climate change.

Huong River is a huge water source but the water distribution in different times of year is very unequal. Very high discharge in rainy season causes flood and inundation, low flow in long dry season often causes water supply crisis, increases water pollution, salinity intrusion, ecological and wild life degradation.

4.2.1 Methodology and data

Meteorological data in the form of precipitation, maximum, minimum and mean air temperatures on land, river runoff were required. The daily records of the maximum and minimum air temperatures, precipitation from 1961-2004, their projections for 2020-2100 and various climatic scenarios were obtained from study “climate scenarios development” in this project.

For calculation of runoff flow caused by rainfall on the basin the Rainfall-runoff model was used. When rainfall, rain distribution change and rain amount lost by evapo-transpiration and temperature increase, the runoff and discharge will change.

Hydrodynamic model used to calculate and simulate the flood regime, the inundation areas, the salinity intrusion for the downstream plain with the context of water resources changing and sea level rise.

In this study, the MIKE11 and MIKEBASIN are used. The computer software for these models and skills to handle this software are available at IMHEN. Also the data for the Huong River Basin are available.

4.2.2 Introduction to NAM model

NAM model is a hydrological model which simulates the rainfall – runoff process occurring at the catchments scale. NAM is the rainfall – runoff (RR) module – a part of the MIKE 11 River modeling system. Being a lump model, NAM treats each catchments as a single unit. The parameters and variables, therefore, are average values for the entire catchments. As a result, some of the model parameters can be evaluated from physical catchments data but the final parameters estimation must be performed by calibration against time series of hydrological observations.

The model simulates the rainfall – runoff process by continuously accounting for the water content in four different and mutually interrelated storages that represent different physical elements of the catchments. These storages are:

- Snow storage
- Surface storage
- Lower or root zone storage
- Ground water storage

4.2.3 Calibration and verification of NAM model for Huong river

The NAM model was calibrated using a set of observed discharge data. As a consequence, it can accurately simulate monthly variation in discharge and total runoff. Subsequently, the model was used to simulate discharge for different time period. The results were compared to observed values in order to independently assess the ability of the model to make simulations more reliable (model verification). For the purpose of estimating impacts of climate change on runoff, the study focuses on the two objectives: total amount and seasonal distribution of runoff.

Table 4.2: *List of sub-basins and rainfall gauges for rainfall – runoff routing by NAM model*

Sub-basin	**Main river**	**Area (km^2)**	**Rainfall Gauge**
Duong Hoa	Ta Trach	775	Thuong Nhat, Nam Dong
Binh Dien	Huu Trach	707	Binh Dien, Ta Luong
Co Bi	Bo	872	A Luoi, Ta Luong, Co Bi
Lateral	Huong	708	Nam Dong, Hue, Binh Dien

Measured discharge data coming from 2 discharge-gauging stations along the tributaries of the Huong River (Binh Dien, Co Bi) are used for calibrating and validating rainfall – runoff NAM model. The set of data from 1981 to 1982 and from 1983 to 1985 were used for calibration and verification, respectively. These results are presented in

Figure 4.1 and Figure 4.2:

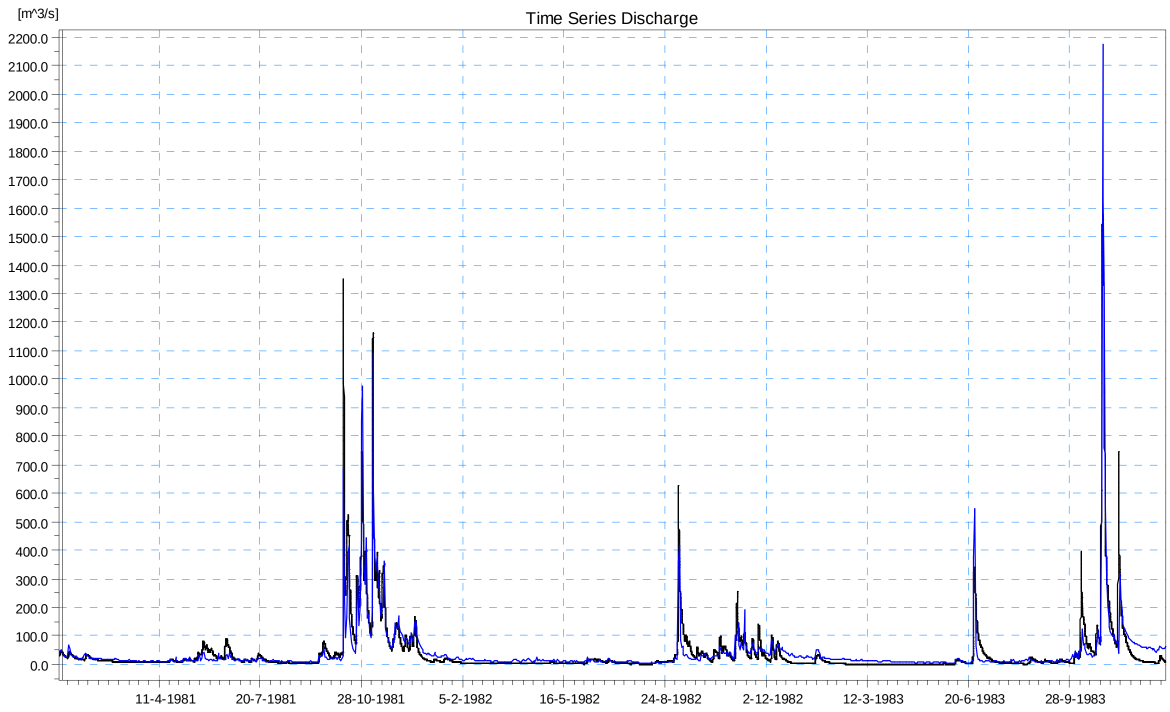

Figure 4.1: *Observed (blue line) and simulated (black line) runoff at Binh Dien station for calibration and verification periods*

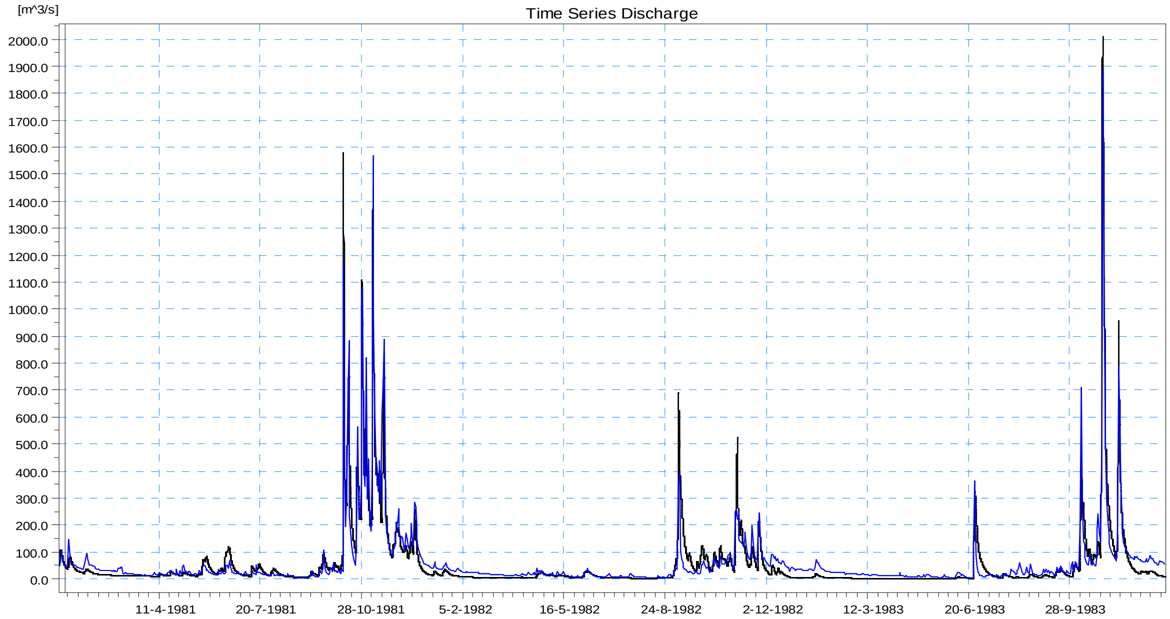

Figure 4.2: *Observed (blue line) and simulated (black line) runoff at Co Bi station for calibration and verification periods*

The performance of the model was assessed by using a model efficiency coefficient. The model coefficient R2 from Nash and Sutcliffe (1970) where 1 presents the perfect match and the smaller values represents worse matches, is calculated the following equation:

$$R^2 = \frac{F_0^2 - F^2}{F_0^2}$$

The initial variance F_0^2 in the equation is calculated by following formula:

$$F_0^2 = \sum \left(q_i - \overline{q}\right)^2$$

Where $\overline{q}$ is the mean observed runoff and q_i is the observed runoff at time step i. The index of disagreement is calculated as follow:

$$F^2 = \sum \left(q'_i - q_i\right)^2$$

In which q'_i is the estimated runoff at time step i and q_i is observed runoff at time step i. The model parameters are selected so that R^2 has the possible highest value.

The results from calibration and verification are shown in

Figure 4.1 and Figure 4.2. There are some differences of the peak flow between computation and observation, the model efficiency coefficient is still over 80% for both calibration and verification. Model parameters after calibration and verification steps proved its fitness and stability so that these parameters can be reliably applied for assessing the impact of climate change on catchments runoff.

Table 4.3: *Calibration and verification results*

Sub-basin	Station	Nash – Sutcliffe criterion	
		Calibration	**Verification**
Duong Hoa	Duong Hoa	87%	80%
Binh Dien	Binh Dien	90%	87%
Co Bi	Co Bi	88%	87%

4.2.4 Flow simulation for climate change scenarios B2 and A1F1

The adjusted CC data of the scenarios were simulated by hydrological NAM model. As examples of outputs from NAM model in the scenario B2 for baseline 1977-2006 and future 2010-2039 and 2070-2099 are compared in the Figure 4.3. Due to the above method of adjustment, the distribution pattern within these 30 years is similar. The comparison results of the runoff changes between different periods under scenario B2 are presented in Table 4.4 and Figures from 4.4. Likewise, the computation results under scenario A1F1 are shown in figures from 4.5.

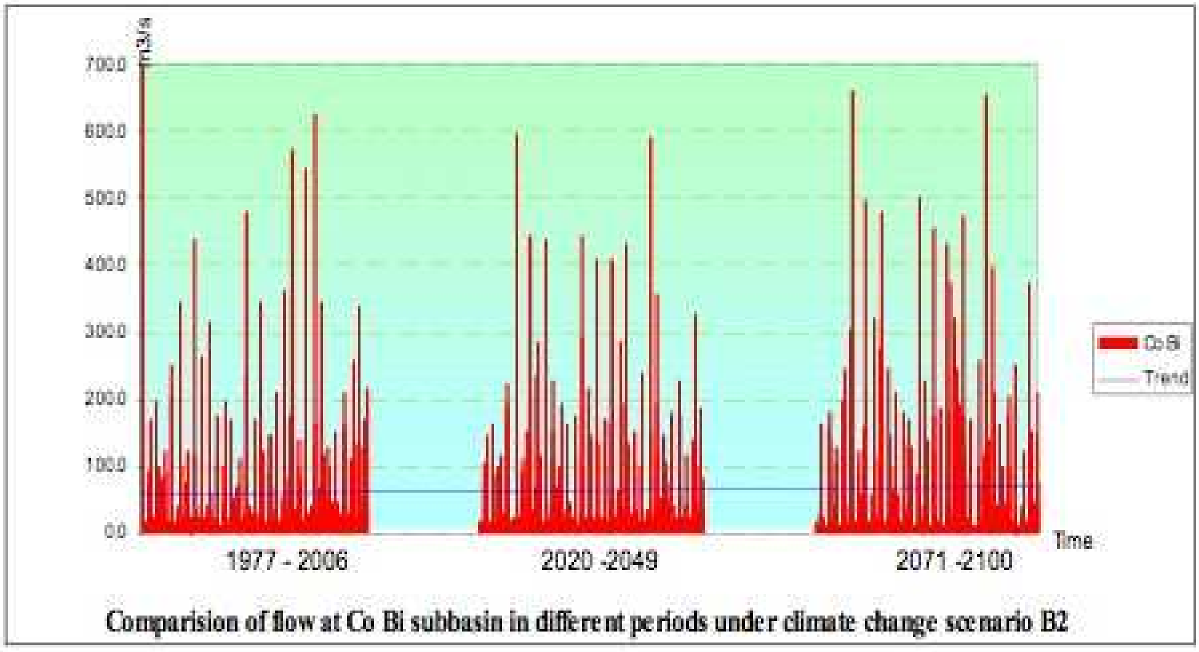

Figure 4.3: *The example of change in stream flow at different sub-basins in the Huong river basin under the scenario B2*

Table 4.4: *Changes in total amount of annual runoff at different sub-basins in the Perfume basin under the scenarios B2*

	Baseline			
Sub-basin	**Duong Hoa**	**Binh Dien**	**Co Bi**	**Lateral**
Average Discharge (m^3/s)	49.0	44.6	61.7	37.8
Total runoff (mm/year)	2147.4	1782.4	2189.3	1652.4

Period	**2020 -2049**			
Sub-basin	**Duong Hoa**	**Binh Dien**	**Co Bi**	**Lateral**
Average Discharge (m^3/s)	52.9	47.6	65.1	38.8
Change (%)	8.1	6.7	5.5	2.7
Total runoff (mm/year)	2324.3	1905.3	2317.0	1700.4
Change (%)	8.2	6.9	5.8	2.9

Period	**2071 -2100**			
Sub-basin	**Duong Hoa**	**Binh Dien**	**Co Bi**	**Lateral**
Average Discharge (m^3/s)	53.4	48.2	67.1	39.8
Change (%)	9.0	8.0	8.7	5.4
Total runoff (mm/year)	2345.6	1928.9	2388.3	1745.4
Change (%)	9.2	8.2	9.1	5.6

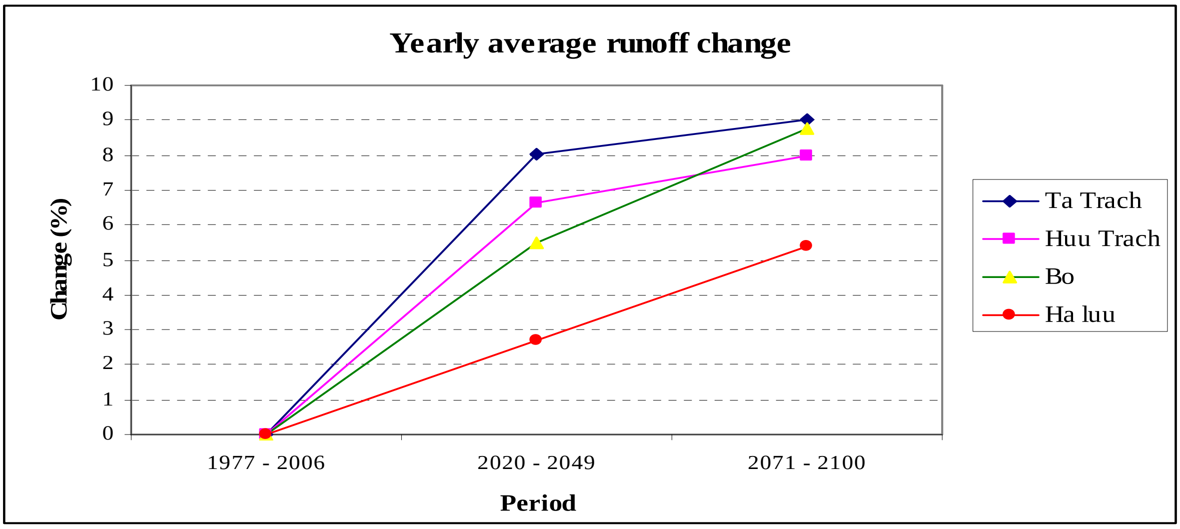

Figure 4.4: *The average change in yearly runoff under scenario B2*

- *Scenario B2:* Increasing annual rainfall leads to higher runoff in the future about 3-8% between the years 2020 and 2049 and 5 - 9% between 2071-2100 in different sub-basins. This increase is caused by the rise of runoff in rainy season from September to December. In this period, the amount of runoff goes up from 3 – 5% in the period 2020 – 2049 to 7 – 10%

and in the period 2071 – 2100. In contrast, streamflow in 3 the driest months from February to April reduces significantly. The change ranges from minus 8-13% for the period 2020 – 2049 to minus 9– 15% for the period 2071 – 2100, causing serious water shortage in low flow season.

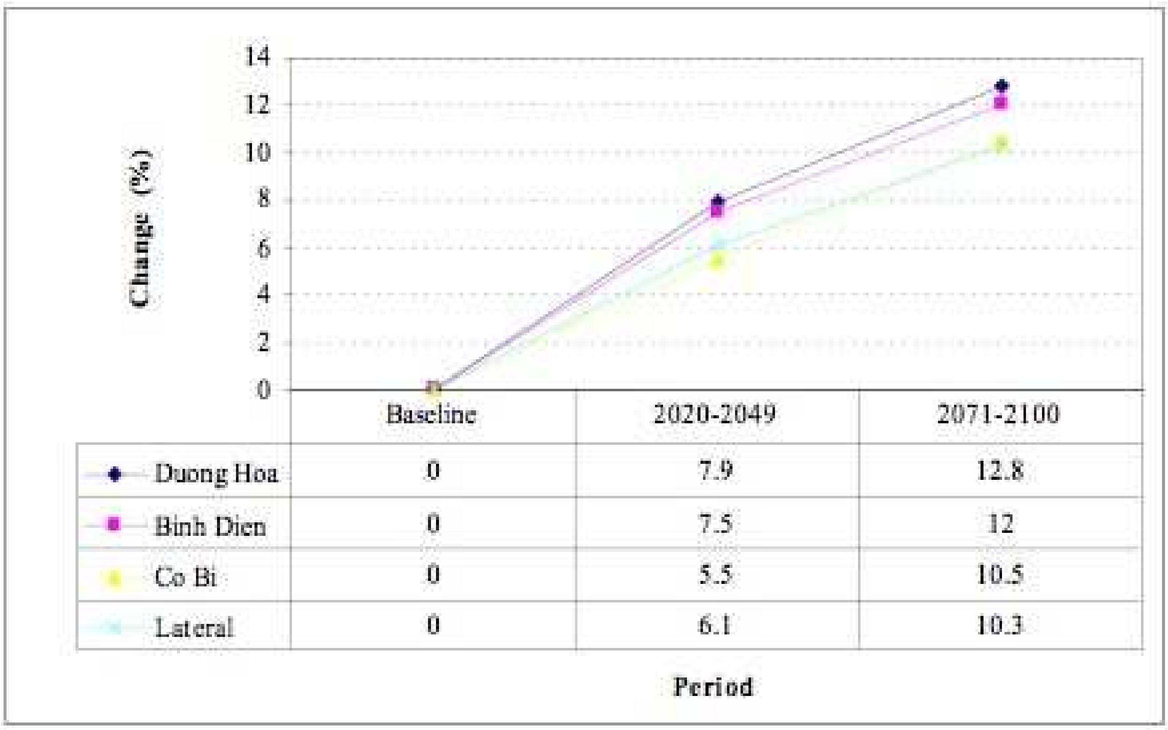

Figure 4.5: *The average change in yearly runoff under scenario A1F1*

- *Scenario A1F1:* Similar to scenario B2, the total annual runoff increases but more quickly. This value increases by from 6 to 8% for the period 2020 – 2049 and from 10 to 13% for the period 2071 – 2100. This increase caused mainly by the contribution of the runoff in rainy season (from September to December). In the period 2020 – 2049, the runoff rise by in the region of 4 – 5 %, while this value in the period 2071 – 2100 varies in the range of 18 – 19%. Due to the fall of rainfall and eva-transpiration, in dry season, the runoff reduces considerably. This value is about -19 to (-)13% for the period 2020 – 2049 and -20 to (-)16% for the period 2071 - 2100.

Table 4.4: *Change in yearly runoff in Thua Thien Hue compared with 1990 (%)*

Basin	Season	2030	2050	2070	2090	2010
Huu Trach	Year	2,02	3,94	5,39	6,14	6,81
	Dec.- Feb.	-0,99	-0,53	-0,92	-1,47	-1,89

	Mar. - May	-3,59	-5,92	-9,64	-12,14	-12,24
	June – Aug.	1,73	4,13	4,42	5,22	7,31
	Sep. – Nov.	3,43	6,38	9,14	10,64	11,52
Ta Trach	Year	2,06	3,98	5,48	6,26	6,94
	Dec.- Feb.	-0,41	-0,54	-0,94	-1,51	-1,85
	Mar. - May	-3,56	-6,08	-9,94	-12,50	-12,67
	June – Aug.	1,92	4,17	4,89	5,83	7,58
	Sep. – Nov.	3,46	6,43	9,24	10,76	11,65
Bo	Year	1,87	3,68	4,98	5,65	6,28
	Dec.- Feb.	-0,31	-0,36	-0,66	-1,15	-1,48
	Mar. - May	-3,59	-6,06	-9,98	-12,60	-12,74
	June – Aug.	1,62	4,13	4,14	4,88	5,81
	Sep. – Nov.	3,26	6,09	8,71	10,13	10,13

4.2.5 Impact of climate change on inundation

4.2.5.1 Methodology

To assess impact of CC on inundation, the study applied hydrologic, hydraulic and GIS based models. By comparing computational results with actual data, the change will be recognized.

In this paper, the hydraulic (HD) and rainfall – runoff (NAM) modules of Mike 11 model were chosen to simulate the evolution of baseline scenario (flood event 11/1999) as well as climate change scenarios in different years (2030, 2050, 2070, 2090 and 2100). Output of MIKE 11 model (water level), then, will be used as an input for MIKE 11 GIS model in order to develop flooded maps for Huong river basin and do some tasks of statistics calculation on inundation for Thua Thien Hue as a whole and Phu Vang district.

In this research, hydraulic computation used the flood event of 1999 as a baseline year. The other years based on this baseline year with assumption that upstream and lateral boundaries were changed comparing to the baseline scenario, downstream boundaries were sea levels corresponding with different sea level rising scenarios respect to the years 2030, 2050, 2070, 2090 and 2100.

Table 4.5 shows the computational water level time series with different sea level scenarios by applying MIKE 11 model. The change of maximum water level in years under climate change scenarios is also estimated. The results are illustrated in Figure 4.6.

Table 4.5: *Change in maximum water level at Kim Long station with different scenarios*

Year	Water level (m)		Change (%)	
	B2	A1F1	B2	A1F1
Baseline	5.81	5.81	0	0
2030	5.85	5.96	0.87	2.08
2050	5.87	6.08	1.56	3.82
2070	5.88	6.16	2.78	4.86
2090	5.90	6.27	3.82	5.73
2100	6.12	6.44	4.51	6.25

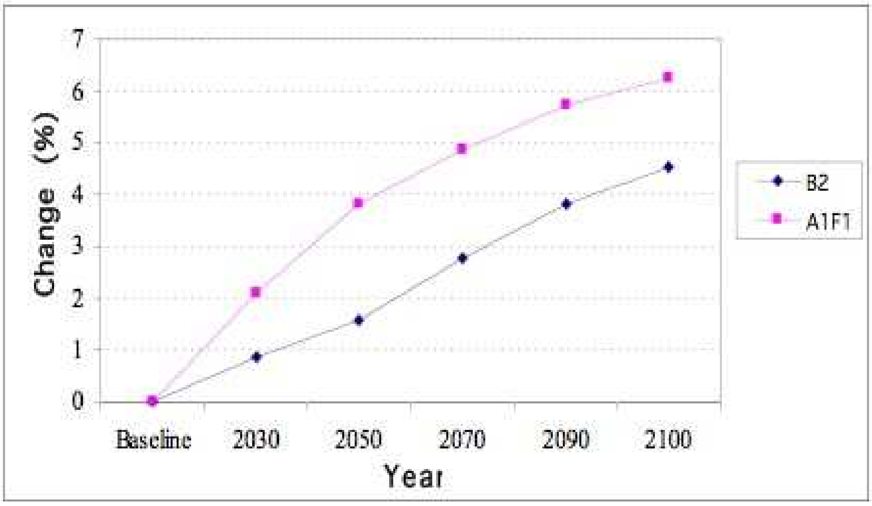

Figure 4.6: *Changes in the maximum water level at Kim Long station with different scenarios*

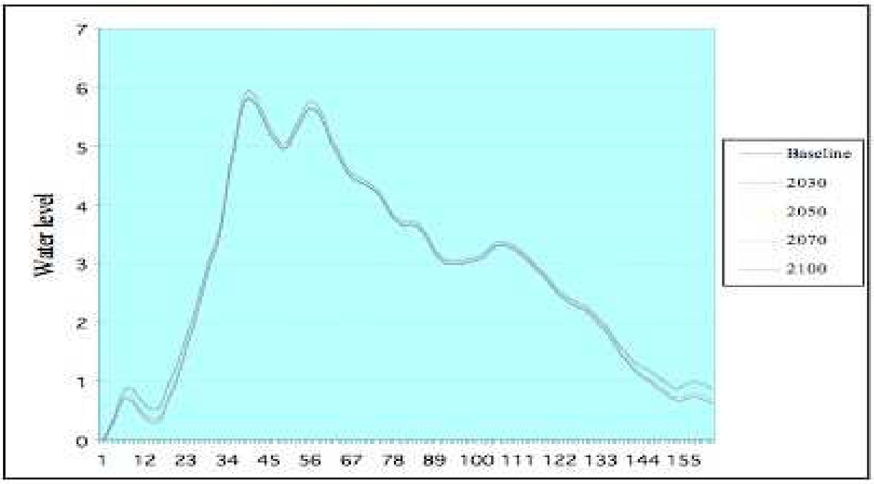

Figure 4.7: *Water level hydrograph at Kim Long station with different years respect to scenario B2*

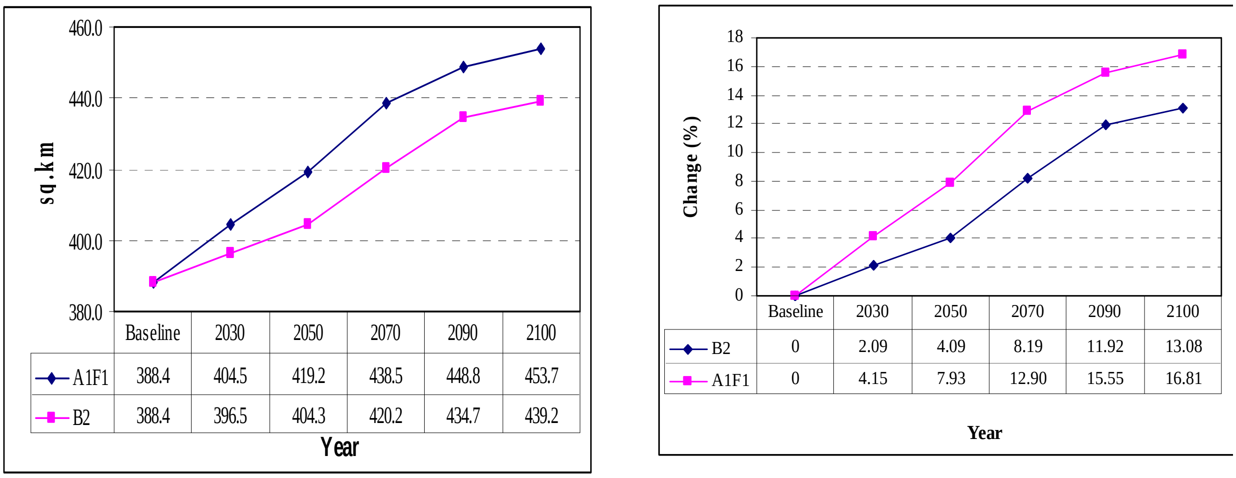

Figure 4.8: *Change in inundated extent of Thua Thien Hue province in years corresponding with different scenarios*

4.2.5.2 Flood Mapping

Basing on MIKE 11 output, MIKE 11 GIS interpolates water level at all cross-sections to construct grid-or TIN-base water surfaces. The water surfaces are then automatically compared with DEM ground elevation to produce flood depth maps. Types of maps produced by MIKE 11 GIS include:

- Flood Depth Map: Maps illustrate the flood depth at each point of the grid
- Comparison Map: Maps illustrate the difference between two flood depth maps.
- Flood Duration Map: Maps indicate in each point, for how long the area has been inundated.

In this research, Flood Depth Map was developed for different scenarios. Figure 4.10 shows an examples of the maps corresponding with H_{max} for the scenario B2.

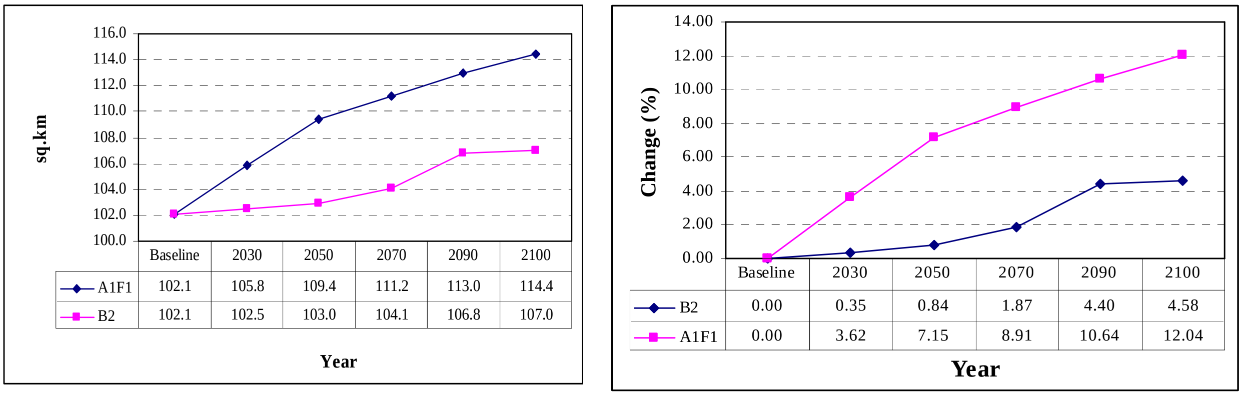

Figure 4.9: *Change in inundated extent of Phu Vang district in years corresponding with different scenarios*

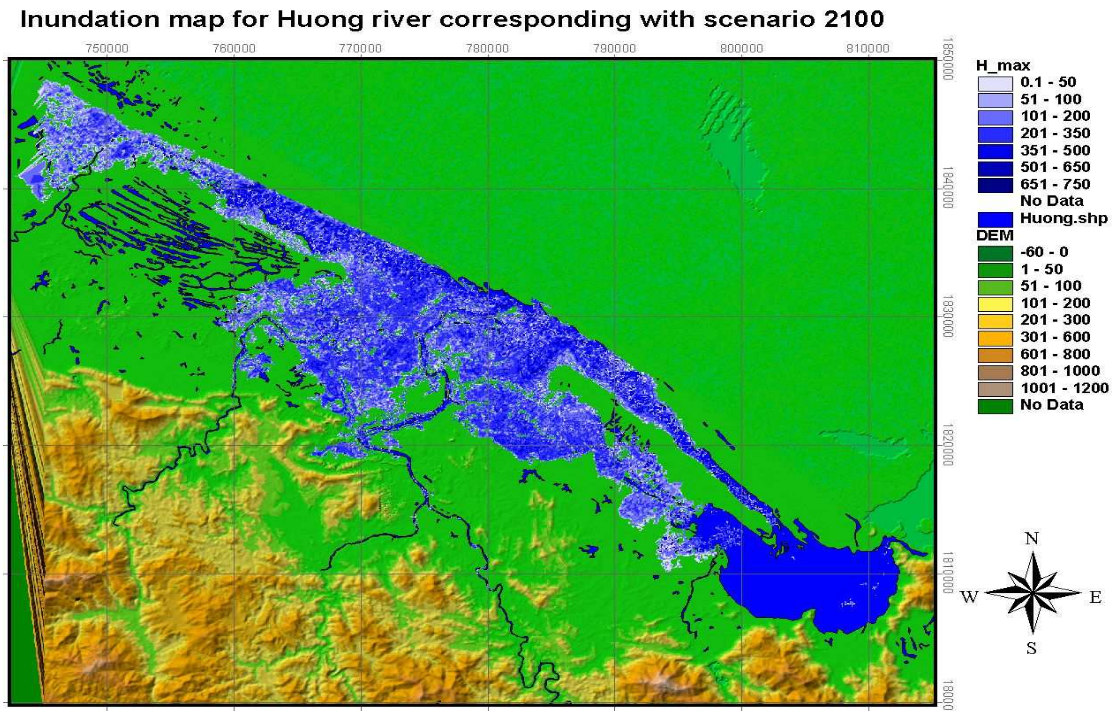

Figure 4.10 - *Inundation map corresponding with the year 2100*

4.2.5.3 Increase of flooded area

In 1999, with the depth of 5.81m, the flooded area was 388.4km^2 accounting for 7.69% area of territory. To the year 2030, with the depth no more than 6m, the flooded area would be already over 400km^2. To the year 2050, with the depth of flooding at 6.08m, the flooded area would be 419.2km^2.

In the following decades, the depth of flooding continues to increase, to the year 2100 it is 6.44m and therefore the flooded area would be up to 453.7km^2, accounting for 8.98% natural area.

Table 4.6: *Flooded area in Thua Thien Hue following scenario A1F1*

Characteristics	**1999**	**2030**	**2050**	**2070**	**2090**	**2100**
Max. depth (m)	5.81	5.96	6.08	6.16	6.27	6.44
Flooding depth (km2)	388.4	404.5	419.2	439.5	448.8	453.7
Flood proportion (%)	7.69	8.01	8.29	8.68	8.88	8.98

4.2.6 Assessment of impact of climate change on salinity intrusion

4.2.6.1 Introduction to MIKE 11 AD module

To calculate salt profile, together with hydrodynamic module (MIKE 11 HD), the AD module of MIKE 11 model is applied. This model is based on solving the one-dimensional advection-dispersion equation which is used for the conservation of mass of a substance in a solution:

$$\frac{\partial AC}{\partial t}+\frac{\partial QC}{\partial x}-\frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right)=-AKC+C_2q$$

where, C: concentration

D: Dispersion coefficient

A: cross-sectional area

K: Linear decay coefficient

C_2: source/sink concentration

q: lateral inflow

x: space coordinate

t: time coordinate

The equation reflects two transport mechanisms:

- Adjective transport with the mean flow
- Dispersive transport due to concentration gradients

The main assumptions underlying the advection-dispersion equation are:

- The considered substance is completely mixed over the cross-section, implying that a source/sink term is considered to mix instantaneously over the cross-section;
- The substance is conservative or subject to a first order reaction (linear decay);
- Fick's diffusion law applies; the dispersive transport is proportional to the concentration gradient.

4.2.6.2 Input

For salinity intrusion computation by MIKE 11 model (using HD and AD modules), the hydraulic scheme is the same as that for flood mapping but not include the Tam Giang lagoon. Moreover, at the present, in Huong river, Thao Long was constructed in the Huong river's mouth to prevent the mainstream of Huong river from the impact of salinity intrusion. With this structure, the impact of climate change in terms of salinity intrusion on Huong river system is effaced. Therefore, in order to assess this type of impact, the research studied only the concurrent of salinity intrusion in natural condition which did not include Thao Long dam in hydraulic scheme

4.2.6.3 Output

After calibration and verification, HD and AD modules of MIKE 11 have been used to estimate the salt profile. Scenarios for salinity intrusion simulation develop basing on change in sea level (sea level rise as above-mentioned). There are six scenarios for salinity intrusion corresponding with scenarios for sea level rise (background, 2030, 2050, 2070, 2090, and 2100). The year 2002 is selected as a baseline scenario because the observed data in this year were the most sufficient among available ones. Results of salinity intrusion computation for scenarios are shown for some cross-sections in the main rivers. The computational results show that there is an increase in salt concentration in years together with sea level rise. This reflects an issue that there is a positive correlation between rise of sea level and salt concentration. Tables 4.7 and 4.8 and show the computation results an increase in salt concentration of Huong river.

Table 4.7: *Change in salt concentration at Pho Nam and Phu Cam cross-sections with scenario A1F1*

Cross-section	Parameter	2002	2030	2050	2070	2090	2100
Phu Cam	Average salt concentration (%o)	2	2.1	2.17	2.33	2.41	2.47
	Percentage (%)	0	5	8.5	16.5	20.5	23.5

Pho Nam	Average salt concentration (%)	2.45	2.65	2.84	3.05	3.24	3.39
	Percentage (%o)	0.00	8.16	15.92	24.49	32.24	38.37

Table 4.8: *Change in salt concentration at Pho Nam and Phu Cam cross-sections with scenario B2*

Cross-section	Parameter	2002	2030	2050	2070	2090	2100
Phu Cam	Average salt concentration (%o)	2.00	2.09	2.15	2.29	2.34	2.37
	Percentage (%)	0.00	4.34	7.55	14.53	17.25	18.44
Pho Nam	Average salt concentration (%)	2.45	2.62	2.82	3.01	3.19	3.35
	Percentage (%o)	0.00	6.86	15.04	22.90	30.05	36.65

Table 4.9: *Change in distance (m) of salinity intrusion of Huong River with the concentration of 1%o and 4%o (m)*

Year	B2		A1F1	
	4%o	1%o	4%o	1%o
2002	14.799	28.632	14.799	28.632
2030	15.258	29.217	15.408	29.327
2050	15.814	29.366	15.927	29.626
2070	16.136	29.565	16.338	29.855
2090	16.261	29.739	16.618	30.133
2100	16.286	29.788	16.786	30.335

The results of salinity intrusion calculated by model have clearly shown that due to effect of sea rise, shortage of water and increase in water utilization in dry season, salt in most rivers in the Huong river system increases considerably. For example, with scenario A1F1, the situation seem to be serious, salt concentration at Phu Cam increase by 23.5% from 2 in 2002 to 2.47 %o in 2100; at Pho Nam this value is 38.37%.

The distance of salinity intrusion, the sea level rise will make salt intrudes further into the river system. As the estimate, until 2100 the distance of salt concentration of 1 %0 and 4%0 increase approximately 1.2 km to 2.0 km depending on scenarios.

4.3 Climate change impacts on biodiversity

Climate change impacts on biodiversity are the changes of environment and habitats of creatures, seriously affecting their lives as well as the activities to protect natural world, including the conservation of biodiversity.

Climate change impacts on biodiversity closely depend on specific conditions:

- For coastal zone, climate change can affect the efforts to build the conservation areas of flood land in lagoons and ecosystems that are posing to threats such as the bird flood land O Lau, the mangrove Ru Cha in lagoon Tam Giang - Cau Hai;

- Sea level rise contributes to speed up the saline of the coastal blackish lagoons, typically the lagoon Tam Giang - Cau Hai, affecting structure of the existing creatures;

- Sea level rise promotes the agriculture to carry out many and thoroughly solutions to prevent salinity, especially construction solutions therefore affecting migratory animals, particularly the emigrant for reproduction such as flower eel, ebony eel and spotted sardine;

- The saline preventing solutions also restrict the ecosystem transiting between the fresh water ecosystem and sea ecosystem, leading to limit the adaptation to the ambience of many domestic animals and crops … as well as wild animals;

- The increase of frequency and intensity of typhoon, flood, drought and hot sunshine… contributes to the process of changing the ecological environment and desertification on sandy area, therefore causes difficulties for the conservation of gene sources…

- The rise of sea temperature also creates a lot of difficulties for the conservation of the coastal coral reefs…

4.4 Climate change impacts on coastal zone

Coastal zone accounts for 30% area and more than 30% population of the province. On the coastal zone, successively from North to South is the Tam Giang - Cau Hai Lagoon, downstream the Bu Lu River, Chan May Bay and the area of Lang Co–Son Tra.

Climate change impacts on socio-economic and environmental activities on the coastal zone include:

(1) Enlarge the flood land on Tam Giang - Cau Hai Lagoon and stretches of coastal plain, increase the effects of flood on the downstream of the Huong River;

(2) Affect the flood land ecosystems; make many mangrove forests disappear;

(3) Erode seashore, restrict cultivated area and inhabiting land, affect negatively the life of local people, including fishermen, farmers and even tourism, particularly in lagoons and downstream Huong River;

(4) Threaten the coastal zone and lowland, industrial enterprises, construction and transport works, waterworks especially sea dyke;

(5) Indirectly increase expenditures for construction and protection of the works in lowland and seaports;

(6) Increase the pollution of water environment in coastal zone, saline intrusion of the Huong River, leading to the scarcity of water;

(7) Indirectly contribute to the increase of unreasonable exploitation of natural resources, dispute, even conflict between branches in exploitation of natural resources in lagoon.

4.5 Climate change impacts on Sectors

4.5.1 Impacts on agriculture

- Almost all rice production areas would be flooded and saline, especially the depression and lagoon. The aftermath is the decrease in food yield and food security is threatened. Therefore, agriculture is considered the national economic branch which is most affected by climate change;

- Some riparian protective forests are flooded and saline, vegetation cover and forest ecosystem change, leading to disappearance of some rare and valuable gene sources;

- Rice, the short-term and long-term planted trees and long-term, newly developed industrial trees such as rubber, may endure more damages when natural disasters increase. The crop pattern, season and even productivity are also affected by climate change;

- The health of domestic animals declines, leading to the rise of animal and poultry diseases;

- Increase the erosion and washing away of soil, the nutrition in the earth goes down, the land becomes arid, decreasing significantly crop productivity;

- Many new pests appear, many plant protection chemicals are used, increasing the danger of environment pollution.

4.5.2 Impacts of climate change on Forestry

Due to climate change, forest ecosystems would be affected in different ways:

- Sea level rise can make the existing mangrove forests province shrunken;

- Some tropical forest plants can move northward and upward to the higher belts while ddeciduous forest with high percentage of drought-resistant trees may growing strongly;

- High temperature combined with rich sunlight may boost photosynthesis, thus enhance tree assimilation process as well. However, the growth rate of forest plants, in terms of biomass, could be reduced due to lower humidity;

- Plants and animals are at higher risk of extinction; particularly some valuable species could become over-exhausted;

- Increase of temperature and drought may cause forest fire, pests outspread and diseases, etc.

4.5.3 Impacts on aquaculture

- Mix up the activity plan of fishery due to changes in season of aquatic farming, shortening and changing some farming objects;

- Change the current in some river mouths, affecting the itinerary of fishing boats and ships and the route of migration for reproduction of fish;

- Change natural environment, leading to changes of biodiversity, the living behavior of aquatic animals and changes of gene sources in nature;

- Especially when temperature over 400C, the growth of animals in farming pools is slow, they even die, affecting the farming productivity; the species of bacteria and fungus develop strongly, causing epidemics and entropy in farming pools at lagoon …;

- The works serving fishery (electricity, roads, levees and canals inside the field…) degrade quickly.

4.5.4 Impacts on industry – energy

Climate change with the increase of typhoon intensity may cause the following impacts:

- Affect the progress of planning and development of industry, the system of conduction and distribution of electricity, system of high voltage and low voltage grids, transformer stations, hydroelectric plants and thermoelectric plants…;

- Disrupt the process of production and trade or prolong the time of producing finished products and the time of keeping in store houses;

- Affect the process of regulating the reservoirs of hydroelectric plants, increase flood that threaten the safety of downstream areas leading to disruption of production in industrial enterprises and thy have to find the ways of prevention;

- Increase the expenditures for maintenance and repair of irrigation and hydroelectric works;

- Increase the danger for technical infrastructure works in industrial parks and handicraft villages…

Temperature rise leads to:

- Increase the expenditures for ventilation and cooling of factories and enterprises;

- Breakdown of electric grid and transformer stations increase, the electricity demand increases and exceeds the load…

Moreover, the increasing of sea level may lead to following consequences:

- Power grid and transformer stations in lowland and coastal zone have to face more frequent danger of flood;

- Changes of big river currents affect the mechanism of regulating the water for some hydroelectric works;

- Some areas specialized in cultivation of industrial materials become narrower;

- Threaten the existing industrial works or production bases that have been designed and built according to water level which has not taken into account climate change effects.

4.5.5 Impacts of climate change on Industry and Construction

Thua Thien Hue has Special Economic Industrial zones Chan May Lang Co, which is serving as the province’s important economic centres located in low-lying in seashore. It is facing with increased challenges in floods from rivers and rising sea level. This requires thorough assessment and more costs for the construction and design of industrial zone and it is necessary that mitigation measures are taken;

Climate change would cause difficulties in water and material supply for industries and construction such as textile, manufacturing, exploitation and processing of agricultural products, forest product and aquaculture products, industrial and domestic construction, and communication. More frequent extreme climate phenomena and natural disasters would reduce life span of materials, equipment, machines, and buildings, whereas maintenance costs would be higher;

These sectors need to review and renovate the plans and technical standards to respond to climate change.

4.5.6 Impacts of climate change on Culture, Sport, Tourism, Trade and Service

Climate change can directly affect the activities in the field of culture, sport, tourism, trade and services etc. of the Thua Thien Hue province;

Sea level rise affects coastal beaches of the province, some of them can be disappeared, the others have to move into inland and exploitation of the beaches may be negatively affected. Sea level rise can damage the culture and historical heritage, preservation areas and related infrastructures of the ancient of Hue city and province;

Due to increasing temperature and shorter cold season, an attraction of the well known tourism areas and resorts in province can be reduced, meanwhile summer tourism season can be longer;

Caused difficulties for developing tourism by ship which has had increasing tendency due to expenditures to reform the works designed following present sea level;

Restrict the areas of concentrated population and urban areas that are places for activities of many forms of tourism;

Increase of epidemics and poverty; therefore destabilize the society, the first and foremost important element in the development of tourism;

Also due to global climate change, the tourist market in Thua Thien Hue has variation in negative direction with the decrease of tourists and their spending of money.

4.6 Climate change impacts on Phu Vang District

4.6.1 Socio-economic characteristics

Phu Vang District has an area of 280.3km^2, near half of which is agricultural land, a remarkable part is special use land which has not yet been used while forestry land and residential land occupy less than 1000ha.

Population of Phu Vang District is 179,137 people (in 2006) living in 19 communes and Thuan An Town.

Phu Vang is a coastal district with many lagoons surrounding in the lower part of Huong river. In the whole 21 communes of the district, 7 ones depending on agriculture, the other seven in the east sea with lagoons surrounding live on many careers, like fishery mainly depending on sea and lagoon economy; and the other seven in the east, which source of income is from lagoon. In the recent years, residents in Thua Thien-Hue in general and Phu Vang in particular have been facing with many difficulties by bad weather and climate change. Extreme weather events like hurricane, typhoons, floods, drought happens more regularly and powerfully resulting in great local socio-economic and environmental loss.

4.6.2 Climate change impacts on the economic and social development of Phu Vang district

4.6.2.1 Coastal zone

Thua Thien Hue and Phu Vang experience high floods in rainy season and droughts and salt intrusion in dry season for the coastal zone. Climate change and sea level rise would make these risks more serious, increase flooded areas, obstruct water drainage, intensify coastal line erosion and salt intrusion which causes difficulties for agricultural production and domestic water usage, and create critical risks to coastal infrastructures such as sea malnutrition, road, docks, and factories and coastal communities. Sea level and sea water temperature rising have potential adverse effects on coral reefs and mangrove forests, biological foundations which are bases for coastal aquaculture and fishery. Therefore, significant investments should be attracted into sea-dyke construction and consolidation, infrastructure development, resettlement of coastal communities.

- Erosion along the shore and estuaries;

- Gradually lose cultivated land by the side of lagoon;

- Saline flooding increases, especially in dry season.

4.6.2.2 Water resources

The fresh water sources become scarcer and water quality becomes worse due to many reasons, including salinity intrusion;

Flood runoff in rainy season increases while low flow runoff in dry season falls down;

Increase of inundation frequency due to typhoon, tide rises up and heavy rainfall on large area.

4.6.2.3 Agriculture

Cultivated land becomes more and more narrow;

Food productivity changes toward worsening tendency;

Food security faces many challenges before the increase of typhoon, flood and other natural disasters.

4.6.2.4 Fishery and aqua-product

Flood land and saline flooded ecosystems have many changes in degenerating direction;

Hydro-physical and hydro-chemical environments, firstly salinity, change, leading to fish migration or contraction of diseases;

Productivity and quality of farming and catching aqua-products decline.

4.6.2.5 Energy, industry and transport

Increase the demand of electricity for domestic use, especially in Thuan An Town and requirement of cooling in aqua-product processing foundations;

The existing infrastructure in the sea port poses to a lot of threats before the rise of typhoon and flood.

4.6.2.6 Health and tourism

Incomes meet with more difficulties; living environment becomes more serious;

Tourist activities meet with more difficulties due to more costly in investment for construction and improvement of infrastructure.

4.6.3 Impacts of natural disasters are increasing

With the main income based on cultivation, catching and farming aqua-products on the large sea and lagoon, Phu Vang faces many possibilities of vulnerability before the increasing natural disasters at the same time with climate change.

The most noted damages may happen in the following conditions:

4.6.3.1 Typhoon and whirlwind

- Ships and boats sink, houses collapse or the roofs are blown up…;
- Crops are damaged, sometimes failure;
- Cattle, poultry, breeding fish and fish for meat, even fishermen are washed away;
- Seashore and saline preventing dyke are collapsed greatly and in many places eroded dozens of meters.

4.6.3.2 Flood

- Erosion on many parts of seashore with hundreds of meters long… sometimes create new estuaries as in the case of Hoa Duan Gate in 1999;
- Infrastructures of electricity, transport, schools, tourism and recreation … are seriously damaged
- Flood increases

The flooded area rises up due to climate change, the proportion of flooded area from 36.4% in 1999 comes up to 40.4% in the same above time landmarks (Table 4.10).

The increase of flood seriously threatens the life and property of Phu Vang People, particularly in coastal zone and lagoon.

Table 4.10: *Area and proportion of flood in Phu Vang District according to scenario A1F1*

Characteristics	1999	2030	2050	2070	2090	2100
Depth of flood (m)	5.81	5.96	6.08	6.16	6.27	6.44
Area of flood (m)	102.1	105.8	109.4	111.2	113.0	114.4
Proportion of flood (%)	36.4	37.2	39.0	39.2	40.3	40.8

Drought and salinity intrusion increase

As mentioned in paragraph 4.1, drought would certainly increase on Thua Thien Hue territory, including Phu Vang. By the end of the century, salinity in river mouths also increases by 20 – 40%, salinity intrusion also goes deeper of about 2km over early period.

4.7 Vulnerability of Thuan An Town

Thuan An Town of Phu Vang District is a depressed plain in the Huong River Delta, beside Thuan An Estuary, at a distance of 13km eastern Hue City. At present, Thuan An Town has 12 villages, in which 7 ones are close to Tam Giang – Cau Hai Lagoon (Dien Truong, Tan Duong, Tan An, Tan My, Tan Binh, Tan Lap, Tan Cang) and 5 ones close to the sea (Hai Thanh, Minh Hai, An Hai, Hai Binh and Hai Tien)

Figure 4.11: *Thuan An commune map*

Through many generations, Thuan An as well as other areas of Thua Thien Hue has been affected by serious weather both in winter and in summer, both in rainy season and dry season. Particularly in recent years, weather and climate have had many abnormal changes. Dry season often lasts long with very high temperature base; in some years (2006) even rainfall only happens by the end of Aug. and early Sept. Winter is still affected by typhoon and tropical depression in combination with the Northeast monsoon…

On the area of Thuan An, often happen various natural disasters: typhoon, flood, drought, salinity intrusion, erosion and salinization. Only during the time from 1983 up to now, there were less than 10 times in which natural disasters caused serious damages for production and life of the people (Table 4.11).

Thuan An Town also has always had to face the troubles in closing and opening of the sea-gates after floods. From 1976 up to now, the sea had eroded deeply into the land 300–400m. The flood of 1999 caused serious erosion of the seashore.

The rise of spring tide is also an aftermath of typhoons and floods in Thuan An.

Table 4.11: *Some natural disasters in recent years in Thuan An Town*

Natural disasters	Year	Month	Seriously affected village	Damage
Big flood accompanied by whirlwind (locally called Ong Lu (Mr. Flood))	1983			Many houses damaged and people died
Big flood	1991			A lot of damages
The flood of 99 – a deluge (0.5–2m)	1999	Lunar Oct.	- Tan My - Dien Truong	- Hai Thanh: 22 people died, 64 houses washed away, 6 houses collapsed, 3 rest houses collapsed, 100%

Natural disasters	Year	Month	Seriously affected village	Damage
			- Hai Thanh - Minh Hai - Hai Tien - Tan Duong	property damaged. - Minh Hai: 8 people died, 4 houses washed away, 30 houses collapsed, 50% property damaged. - Tan My: 3 people died 4 houses washed away, 11 houses collapsed, 50% property damaged. - Dien Truong: 2 people died - Hai Tien: 7 houses collapsed, 13 houses washed away, 30% property damaged. - Tan Duong: 8 houses collapsed, 7 houses washed away, 50% property, fish nets and instruments damaged and lost. **Total damages of whole town** Whole town had 35 people died, 5 injured, 212 houses collapsed and washed away, 617 houses damaged, more than 5000 people endured hungry and coldness, lack of food, 1 km of Hoa Duan Strait broken creating new estuary. The entire infrastructures of electricity, roads, schools and stations were seriously damaged, the dyke of Quy Lai Tan My collapsed and broken in many parts, nearly 317 aqua-product farming households lost all of their properties, estimated damages up to 9 bil. VND.
Flood (1-2m)	2004	11	Depressed villages by the lagoon	- Total damage values: 500 million VND - Collapse on National Highway 49A from Dien Truong Bridge to Tan My electricity station - Dyke of Quy Lai TanMy collapsed of 750 m3, 5 houses collapsed, 15 houses damaged - Aqua-product farming: washed away 750,000 breams, 250,000 tilapias, 10 cages of chainman fish and hinds - Collapses and deep erosions in 10 – 15 parts of seashore from Hai Tien to Hai Binh of 500 m long (Report 113/BCUB, Thuan An)
Big flood	2005	Month 10	Hai Binh	Collapse of 50m
Flood of grain fills (0,5 -1m)	Every year	Month 5 - 6		
Typhoon No. 8	1985	Month 10	Tan Binh, Tan Duong (2 villages living on water surface), Hai Tien, Tan My	- Tan Binh: 21 people died, 16 boats washed away, all the rest fishing instruments were seriously damaged - Tan Duong: 4 people died, 6 houses washed away, fishing instruments lost 100% - Hai Tien: 3 people died, 60% houses and 30 – 40% ships damaged - Tan My: 5 people died, 8 houses washed away, 50% bamboo baskets for catching fish damaged - Total number of people died in the whole commune: 60 people died and missing
Typhoon No. 8 combined with spring tide	2001	Month 11	Losses in agriculture and aqua-product farming in Minh Hai, Hai Thanh	Seashore erosion into the land 4 – 10 m deep, 500 m long 2 rest houses collapsed, 6 houses of level 4 collapsed (Report 114/UB – CB, Thuan An) Some parts of saline prevention dyke of Quy Lai Tan My collapsed
Typhoon No. 8	2005	Month 11	Hai Tien	- Area for cultivating vegetable and other crops damaged by 100%, rice wet, cattle and poultry washed away, breed fish and fish for meat, fish net and fishing instruments washed away

Natural disasters	Year	Month	Seriously affected village	Damage
				- Many parts greatly collapsed, particularly the part from villages Hai Tien to Hai Binh of 700m long was eroded of about 20m - 9 houses collapsed, 42 houses with roofs blown up, 2 fishing ships sunk and protection forest washed away
Salinity intrusion	1998		Dien Truong Village	Agricultural field was affected by salinity, crop failure

In the past years, Thuan An has experienced many special extreme climate phenomena. Many of them have affected the local socio-economic development. Many projects, infrastructure, and potential policies in developing the local economy has been built up and deployed. Other changes in power resources and phenomena relating to local weather regulation have been getting complex and more intensified, which affecting local residents' livelihood

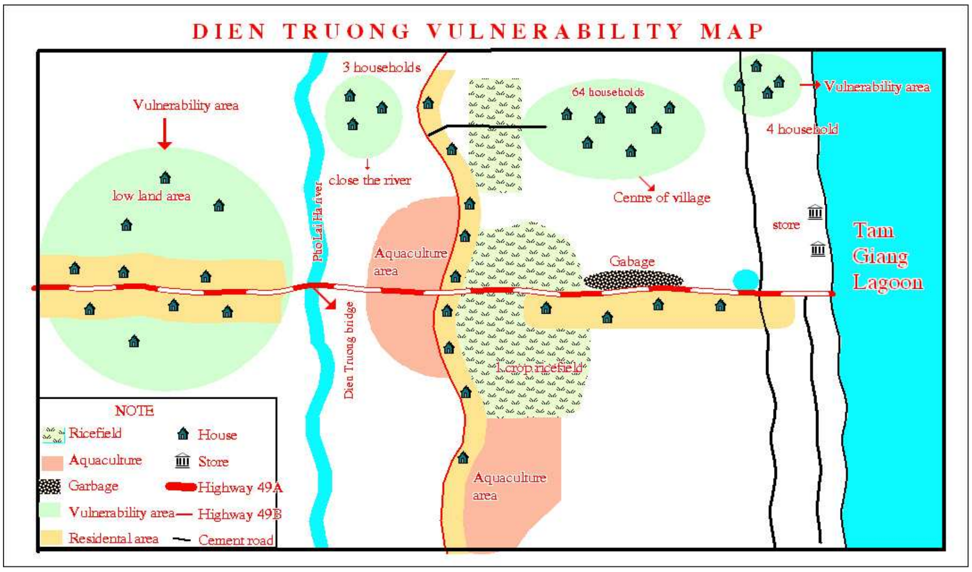

Figure 4.12: - *Map on vulnerability in Dien Truong village, Thuan An town, Phu Vang district, Thua Thien Hue province*

4.8 Climate change impacts on Chan May Lang Co area

According to the direction of economic development to the year 2020, the economic zone Chan May Lang Co is a great international economic and transport center of Central Vietnam. Landscape of Chan May Lang Co economic zone is created by Chan May Bay, Thua Luu - Nuoc Ngot Plain and Lang Co Town, including Lap An Swamp. On the area of Chan May– Lang Co there is a free duty trade area of 962 ha, industry park of 560ha, Chan

May Port with total land and water area of 684ha, Chan May Town of 1650ha, and the tourist Lang Co - Canh Dương - Lap An Swamp area of 3700ha.

In recent years, the area Chan May– Lang Co has been affected by many typhoons, mainly of wind force scale from 9 - 12, storm surge up to 1.5m in typhoon No. 6 in 2006 and 1.7 m in typhoon CECIL in 1985. Moreover, here there have happened many other natural disasters: flood, flash flood, whirlwind, landslide, collapse of river bank and seashore…

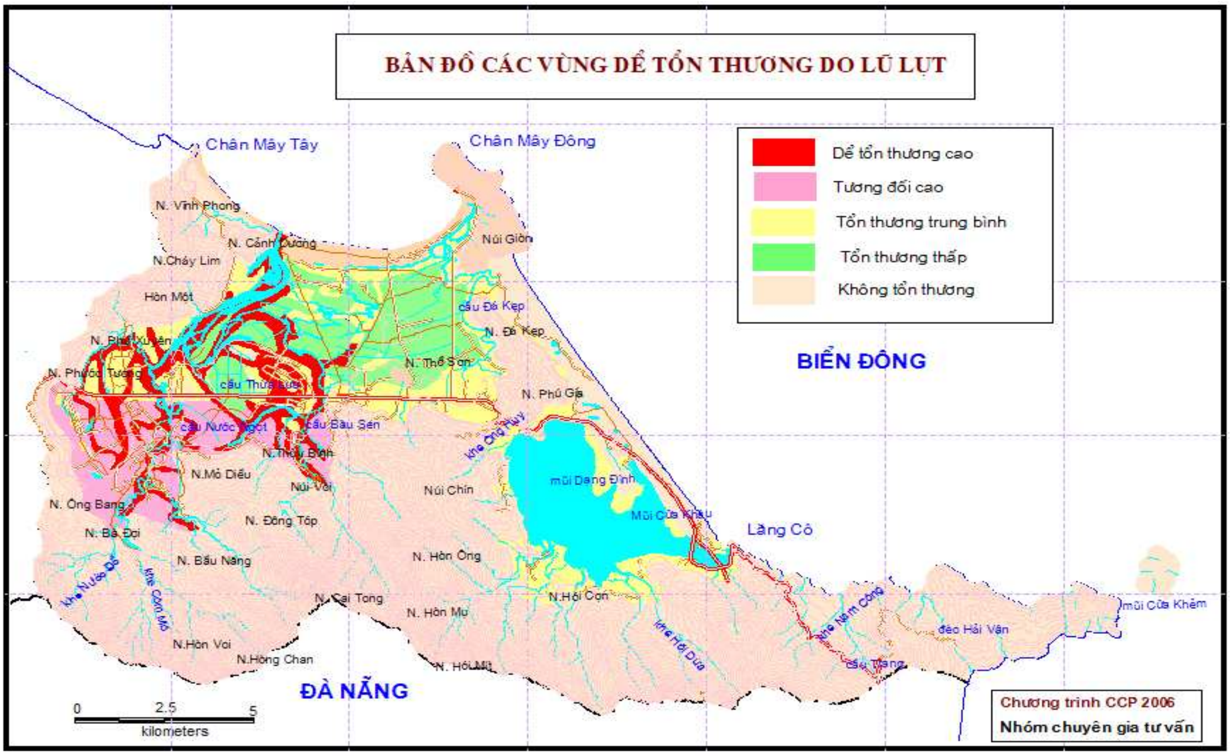

Figure 4.13: *Vulnerability Map by flood of Chan May Lang Co Economic Zone*

4.9 Conclusion

Global warming lead to increasing temperature and change in precipitation pattern in the Vietnam and Thua Thien Hue. Increasing annual rainfall leads to higher runoff in the future in different sub-basins. This increase in rainy season leading to increase the number and intensiveness of flood.

In dry season climate change causes serious water shortage and low flow and due to effect of sea rise, the salinity increases considerably in most rivers in the Huong river system. Climate change and sea level rise have serious impacts on coastal zone and different areas of the province especially coastal districts as Phu Vang district and Thuan An Town, Chan May Lang Co economic zone.

Temperature rise would also badly affect such sectors as energy, transportation, industry, construction, tourism, trade, etc. High temperature and humidity would elevate pressures on human health, especially for old people and children, and cause diseases, particularly tropical and infectious diseases by favouring growing condition of bacteria, insects and diseases vectors

The climate change has potential impacts on natural ecosystems. It would cause shifts in thermo-border of continental ecosystems and fresh water ecosystems as well as shifts in flora and fauna structure in certain regions. Degradation of biodiversity would accelerate due to loss of some temperate and sub-tropical species.

For agricultural production, cropping pattern and livestock may be changed in some regions. Temperature rise with higher variability (both maximum and minimum temperatures) will combine with other climatic extremes and natural disasters to induce pestilent insects and diseases to wide spread. Consequently, agricultural production and food security would be seriously threatened.

CHAPTER 5
ADAPTATION MEASURES TO CLIMATE CHANGE IN THUA THIEN HUE PROVINCE

5.1 Introduction

In global context, the climate change issues, its impacts and adaptation became a hot pot for policy making process in most countries. It became a part of the compliance of international agreements on global climate and environmental problems. This is an actual global trend and all countries including Viet Nam have to comply.

Thus, taking into account a climate change problems, its impacts, future trends and uncertainty factor as well as mitigation and adaptation mechanisms in the policy making process could open new opportunities, financial, technical and technological support for Vietnam from all over the world. That would also bring into the policy development and implementation process the new scientifically based knowledge and arguments, new approaches of pro-active preparedness and prevention rather than passive response to the problems or recovery aftermath, with the view to future scenarios and trends. In the future, when the adverse impacts, extreme events or disasters really occur, it will help in coping and relief activities, mitigating the damages and losses of property and human lives.

Until certain extent, people have always been trying to respond and adapt themselves to the climate variability's and changes, the extreme weather events and disasters. However, in case of stronger, larger or more severe disasters, they would usually expose their lives and properties to high risks and dangerous impacts, their responses may become chaotic, scattered and inefficient.

The most vulnerable to all types of impacts and dangers are always the poor people and special sensitive contingents: the elders, the women and children. That why many disaster casualties, especially the floods and storms in Viet Nam belong to the elders, women and children. In that case, they need very much well organized help and guidance, concrete and urgent measures from local, provincial and central authorities in relief and rescue works, after-disaster aid and recovery. Moreover, they need to be informed, early warned about the events, and good trainings for different types of impacts.

The policies need to be made for the people interest of safety and prosperity, but at present are not yet in such condition so far. We definitely need quality intervention in the policy making, planning and managing processes in Viet Nam at all levels of authority.

In practice, Viet Nam governments and communities could help offset the costs by undertaking adaptation measures. The question is determining which adaptation measures are best in the face of uncertain future impacts. At this time, adapting to climate change may soon become an economic and political imperative.

In such a highly disaster-prone province like Thua Thien Hue of a disaster-prone country like Viet Nam, people always have experiences and empirical knowledge for hundred years in adapting to and coping with climate related impacts and "usual" extreme events (typhoons, storms, flood and drought), in their particular locations and they obviously have very good ideas. By these reasons, the adaptation process has to be done with local knowledge and local characteristics.

5.2 Climate change adaptation options in Huong river and Thua Thien Hue province

The Vietnamese as well as Thua Thien Hue people have a thousand year long tradition of confronting and fighting natural disasters. But identifying adaptation options to long-term human-induced climate change is new concept, but does not come from a scratch. The traditional measures taken to adapt to climate variability such as dyke system building, flood diversion and retardation structures, weather forecast will still be exploited intensively.

However, future human-induced climate change will impose not only on the change in climatic variability, but also the frequency and intensity of extreme events that definitely will harm the long-term sustainable development of the country. The most focus of adaptation options is aimed at the country's most susceptible sectors to future climate change, including water resources, agriculture, forestry, aquaculture and coastal zones, energy and transportation, and health.

One of the most compelling arguments for acting now is the rising impact of extreme weather events in Viet Nam and Thua Thien Hue. Even those who argue that climate change may never happen cannot dispute the urgency of reducing the coastal zone vulnerability against severe climate events. The recent drought, floods and the sequence of cyclones which affected Thua Thien Hue province during the 1990s attest to an increasing exposure that will, sooner or later, put mounting public pressure on governments and politicians to act. No less compelling is the fact that under an increasing globalize economy, those countries which invest early on adaptation and in the process improve the quality of life and reduce investment risks are likely to hold a competitive advantage for foreign investment. As measures to reduce vulnerability are also among the most effective in adapting to climate change, acting now to reduce current vulnerability will also prepare Viet Nam government in general and Thua Thien Hue province in particular for the long-term effects of climate change.

Another reason for acting now is that failure to do so may result in a loss of opportunities that may not exist in the future.

Finally, adaptation strategies may require several decades to be discussed and implemented. Communities living in low-lying areas, for example, may need to relocate further inland into other communities' customary land. This will require extensive public debates on how to place the common good of all above the good of the clan or immediate family, a process that cannot and should not be rushed.

A development path that takes adaptation into account might sacrifice some potential short-term gains in favor of more diversification and a reduction in vulnerability. But it would vastly decrease the downside costs should climate change scenarios materialize. The challenge will be to find an acceptable level of risk — an intermediate solution between investing in high cost solutions and doing nothing — and start adapting long before the expected impacts occur.

5.2.1 Climate change adaptation for coastal zone

A coastal zone management framework that is tailored to the socio cultural conditions of each island should be used for adaptation planning. This framework should have three major goals: preventing loss of lives and property, avoiding development in inundation-prone areas, and ensuring that critical coastal ecosystems, such as coral reefs, are protected and remain functional.

In Thua Thien Hue province, adaptation to climate change in the coastal zone is expected to be at highest priority. Main impacts would cause sea level rise, flood, drought and salinity intrusion.

Basic principle for climate change adaptation in coastal zones is to ensure integrated management and sustainable development, food security, people safety, and maintain cultural assets under serious impacts of climate change and sea level rise.

The provincial authority has constructed a number of dikes and dams to contain the flood waters and prevent salt water intrusion. Yet, the devastating floods of 1999, indicate the shortcomings of this structural approach to flood management and mitigation. An alternative solution that is based on an integrated management approach of the basin is being considered.

Such an integrated approach can also address the current over-exploitation of resources in the basin and the lagoon.

At local levels, very few activities are carried out on flood vulnerability reduction, water resources protection or resource rehabilitation. Most local work has been disaster relief. Other investments, for example in water supply, sanitation and pollution mitigation and prevention have been extremely small or absent. Huong river basin should be managed sustainably to reduce flood vulnerability and improve the livelihoods and quality of nature.

Lagoons, small bays, deltas, sand beaches, islands, soft and hard sea beds, and brackish aqua-cultural ponds have varying structures and functions. There are many fishery and farming activities along the lagoons. More then 300,000 people, mostly poor, are living along the lagoon. The problem of managing of the entire system needs deep analysis.

Hue and Huong River are World Heritage sites and tourist places. Protection and adaptation for Huong river system to any change is very important for these activities.

The coastal zone of the river basin, including Phu Vang district, is a very complicated combination of downstream flows and the unique Tam Giang - Cau Hai lagoon system with some poorest, most vulnerable communities of fisher folk and peasant households.

Specific adaptation options could include:

- *Protection of towns and population areas.* Construction of sea dyke is likely to be the measure of choice to prevent erosion in densely populated coastal areas. However, sea dyke do not resolve the underlying cause of erosion, and they can promote offshore movement of beach sediments. They are also costly to build and maintain, and they will need to be extended as the sea level rises. Sea dyke should be used only to protect valuable property and buildings that cannot be relocated. For new infrastructure, the use of setbacks and relocation could be considered.
- *Land use policies.* Land use policies should encourage settlements away from low-lying and high-risk coastal areas through, for example, the use of coastal hazard mapping.
- *Prevention of erosion.* Depending on the infrastructure and population density, adaptation options to prevent coastal erosion of Thua Thien Hue may include (i) accommodation, where property is replaced as it is damaged; and (ii) shoreline protection, in areas with large populations and significant infrastructure. In low lands, where it is essential to retain over-wash sediments, and other coastal

vegetation to promote shoreline accretion, closing or narrowing selected passages between the lagoon and the ocean, and the strategic use of groynes to help minimize the transfer of sediments from the ocean side to the lagoons. Groynes, however, should be used only in key locations, such as the passage edges, as they tend to cause downstream erosion and require continuing maintenance. In less developed areas the use of setbacks to control future development, beach nourishment and relocation of infrastructure might be preferable.

- *Protection against inundation.* On areas with little infrastructure, the costs of protection are likely to be prohibitive, and relocation or modification of structures to accommodate surface flooding could be considered. On the more populated strategies to allow over-wash sediment to naturally increase the elevation of the coastal may help offset the impacts of inundation. Where land ownership disputes are not an issue, new structures should be set back from the shoreline and elevated to allow for periodic flooding.

- *Population relocation.* If all other measures fail, population relocation may need to be considered. While some communities may opt to move on their own, population relocation would pose immense social and political risks for Thua Thien Hue governments, as nearly all inhabitable land is under some form of customary ownership.

According to these options, pay attention to both natural adaptation and organized adaptation measures, including the following:

a) Protection:

✓ Build sea dyke and dam from Thuan An Estuary to Tu Hien Estuary to prevent salinity

✓ Build new dyke for Huong River

✓ Consolidate and raise the existing dykes and dams

✓ Raise the foundations of coastal structures

✓ Establish non-structural areas and put forward new construction practice

✓ Protect and enlarge flood plain forest/mangrove forest, new belts of forests to protect sea dyke such as casuarinas forest and eucalyptus forest...

✓ Strengthen integrated management of coastal zone, catchments and lagoons.

b) accommodation

Following this option, accept some losses following the direction to regulate infrastructure and living habit of coastal residents:

- ✓ Build infrastructures adapting to climate change or reform these foundations following the direction to adapt to climate change.
- ✓ Step by step transfer to sustainable techniques of agriculture cultivation-aquaculture
- ✓ Organize communication and warning on climate change
- ✓ Raise awareness and build capacity of adaptation for local officers and people
- ✓ Train key officers participating in activities to adapt to climate change
- ✓ Invest into scientific research, especially methods to forecast climate using the numerical models
- ✓ Integrate climate change policy consideration into the planning and development of strategy and actions of province to respond to sea level rise and extreme phenomena.

c) Evacuation

- ✓ Organize resettlement or move infrastructure out of the threatened areas
- ✓ Evacuate people from flooded areas

5.2.2 Adaptation option to climate change in water resources

a) Constructional solution

- ✓ Build dams and reservoirs to store water, control flood and regulate water in dry season
- ✓ Upgrade and enlarge system of irrigation and drainage in order to protect and exploit the cultivate areas effectively
- ✓ Upgrade the existing sea dyke and river dyke, gradually build sea dyke from Thuan An to Tu Hien Estuaries

- ✓ Maximum protection for reservoirs, which has most special importance in Huong river system.

b) Non- constructional solution

- ✓ Water resources management and access considering climate change impact and increasing of water demand
- ✓ Develop and improve the mechanism in integrated water resources management (IWRM) on catchments scale, particularly the advanced practice to operate reservoir and hydroelectric system
- ✓ Decrease the rate of population growth
- ✓ Organize agricultural production on waste land, particularly the hilly midland; improve the techniques of agricultural cultivation and aquaculture
- ✓ Protect and develop riverhead forest in A Luoi and Nam Dong
- ✓ Perfect the efficiency of water use; regulate dry season runoff through reservoir
- ✓ Promote public awareness on safe and reasonable use of surface and underground water

Conduct researches into long-term forecasting and planning of water use by model

5.2.3 Adaptation to climate change in agriculture

- ✓ Build dams and reservoirs to store water, control flood and regulate water in dry season
- ✓ Upgrade the canals for flood discharge, irrigation and drainage system, and pump stations to serve agriculture. Use water more effectively for irrigation.
- ✓ Develop crop pattern suitable for climate change condition; plant new breeds that can endure severe weather such as flood and drought...
- ✓ Change the crop pattern, domestic livestock at high risk areas, focusing on the area with low effectiveness of rice production to aquiculture.
- ✓ Conserve and maintain local species, establish the bank of cereal breeds.
- ✓ Research and apply high technology in agriculture for high quality and quantity production and protect the environment and suitable for climate change conditions.

- ✓ Test and experiment on crop varieties which overcome waterlogged, drought and other disasters.
- ✓ Raise awareness and disseminate knowledge on climate change and adaptation to climate change for farmers
- ✓ Develop and upgrade the model of garden-pool-cattle shed production (VAC)
- ✓ Create jobs and increase income for farmer in flood season and when free from agricultural work

5.2.4 Aquaculture

- ✓ Revert to the original state of lagoons, low effect of feeding areas. Focus on high tide feeding areas, pool on sand. Develop more feeding cage model.
- ✓ Offshore fishing management.
- ✓ Plan the aquiculture processing, materials product supply in climate change condition.

5.2.5 Climate change adaptation options in forestry

- ✓ Step up reforestation, firstly in riverhead, re-vegetation of waste land and bare hills in mountainous area such as A Luoi and Nam Dong; protect catchments through forest development.
- ✓ Protect the existing mangrove forest and newly plant some of them. Manage flood land forest and mangrove forest, new protection forest, casuarinas forest and eucalyptus forest...
- ✓ Protect natural forest and advance towards enclose the forest
- ✓ Prevent forest fire in dry season, educate and campaign for stopping the burning of forest; strictly control and severely punish those who deforest
- ✓ Establish the bank of natural forest tree breeds to protect the rare and precious species
- ✓ Upgrade the technique of processing wood and restrict the use of wood
- ✓ Select and develop the breeds of trees that are suitable for conditions of climate change and severe natural conditions

- ✓ Develop and implement the forestation program or projects to green bald land area, forestation on sand dunes along seashore, the mangrove forest areas in and lagoons, protect from erosion and improve the ecological system of sub-areas.

5.2.6 Adaptation options for Industry

- ✓ Apply the advance of new technologies not only to adapt with climate change but also take a part in greenhouse gases emission reduction.
- ✓ The design project of titanium exploitation and glass sand shops need to be carefully considered climate change information in order to against with huge storms, whirlwind or sand storm. The areas, where already been exploited, must be return to the first status and grow trees to against erosion and flying sand.
- ✓ Upgrade infrastructure investment (for example: roads, electric network, water supply system…), by the way, business processing must be improved to cope with disasters, which caused by climate change.
- ✓ Plan industrial groups or industrial points, industrial center focus on coastal zone, where have no effected by erosion and link to other technical infrastructures,
- ✓ Research and assess the exploitation potential and capacity of geothermal energy of hot water mines in A-roan (A Luoi district) and Tan My (Phu Vang district).

5.2.7 Adaptation options for Construction and Transportation

- ✓ Projection the urban areas, rural areas must be considered location, geography using climate change information.
- ✓ Revision and renovation the design standards for building, transportation, water conservation construction, hydropower under the climate change impact assessment, which will be used as criteria for sustainable social economic development plan
- ✓ Develop and expand the ecological commune model and ecological urban centre, including using renewable energy, clean energy to reduce the greenhouse gases emission.
- ✓ Plan for resettlement; stabilize the living in river shore, hydro powers.
- ✓ Re-projection the urban centre development plan, with climate change consideration.

- ✓ Assessment of climate change impact to reservoir, hydropower construction before execute.

5.2.8 Adaptation options for Public Health

- ✓ Adaptation strategies to minimize public health impacts do not require extensive new interventions. Rather, existing initiatives that reduce the vulnerability of the population, and particularly the poor, should be enhanced. Actions should include not only improving public health but also strengthening the resilience of the ecosystems on which the population depends for food and income. Specific measures could include:
- ✓ Integrated adaptation strategies: Adaptation strategies should include a range of interventions to reduce the vulnerability of the population, such as improved sanitation and water supply, management of solid and liquid waste, protection of groundwater, reduction of poverty (particularly among urban squatter settlements), increased access to primary health care, and protection of subsistence food supplies. Many of these measures would also help control the incidence of diseases.
- ✓ Control of dengue fever. Adaptation strategies should include further support to vector control programs that collaborate with communities to reduce mosquito breeding sites. They should also improve epidemic preparedness through vector monitoring, early warning systems, and better preparation of primary health care facilities to treat dengue hemorrhagic fever and dengue shock syndrome.
- ✓ Improve the socio-economic conditions and living standard of the people, particularly poor people and evacuated people; promptly implement the program on poverty alleviation in local level
- ✓ Establish criteria on building houses for every locality with the considering of the possibility of climate change and natural disasters
- ✓ Seriously quarantine the border areas and airports to prevent the dissemination of epidemics from other areas.

5.2.9 Adaptation options for Tourism

- ✓ Fulfill the detail planning of the key tourist areas as the basis for projects of investment and development in these areas. Parallel to planning, strengthen invest into infrastructure of tourism services suitable for policy of adaptation to climate change

- ✓ Continue the research into promulgate the stipulations and regulations on management of the key tourism areas and environment criteria…of tourism points in compliance with climate change adaptation policy
- ✓ Have the policy to encourage investment into exploiting the potential of natural tourism to serve the development of sustainable ecotourism
- ✓ Conduct specialized research into market of ecotourism in the context of having to implement the solutions of adaptation to climate change
- ✓ Train and build the staff of ecotourism guides, organize workshops, meetings to exchange experience on development of tourism towards friendly to environment and adapting to climate change

5.2.10 Adaptation options for Biodiversity

- ✓ Continue a research, basic investigation and evaluation of the values of biodiversity in different ecosystems: forest, sand dune, lagoon and sea. To do research into feasible solutions to rehabilitate ecosystems, especially the coastal ones such as mangrove forest, aquatic weed in lagoon, coral reef and sand dune.
- ✓ Focus on establishing the conserves of biotope and biodiversity which have been included in the development strategy of province.
- ✓ Forest fire management strategy, preserve stringent protective forest. Forestation prefers use local plant which adapt to extreme climate.
- ✓ Prepare plan and measures to prevent and annihilate harmful creatures. Firstly, focus species that adapt to damp and wet lands.

5.3 Solutions of climate change adaptation option in Phu Vang District

5.3.1 Water resources

- ✓ Review the planning of irrigation and drainage and gradually consolidate and repair canals to ensure the efficiency of reasonable irrigation and drainage

- ✓ Build new sea dyke Thuan An–Tu Hien according to provincial strategy of adaptation to climate change
- ✓ Consolidate the system of boundary dyke to prevent flood and saline flood according to provincial strategy of adaptation to climate change
- ✓ Step by step perfect the mechanism of water resources integrated management in the district area.

5.3.2 Agriculture-Forestry-Aquaculture production

- ✓ Review and adjust the planning of crops and crop seasons to be suitable for the context of climate change
- ✓ Pay attention to improve cultivation technique to ensure stable productivity of crop in the condition of more severe weather and more natural disasters
- ✓ Pay attention to improve technique of aquaculture suitable for the hydro-chemical and hydro-physical changes
- ✓ Have long-term plan to guarantee food security before for situation of typhoon, flood and other natural disasters
- ✓ Care for, protect and develop mangrove forest and protection forest along the coastal areas
- ✓ Develop planting of scattered trees among households and on unused land.

5.3.3 Industry, energy and transport

- ✓ Develop and implement projects on: Use solar energy, decrease the consumption of wood for energy in domestic use and use wind energy for irrigation and drainage to minimize the electric power for agricultural production.
- ✓ Adjust or change some criteria of designing the structures of transport, architecture, aqua-product processing industry, the foundations of education and health care… to respond to sea level rise and increase of flooded area.

5.3.4 Public health

- ✓ Raise the public awareness on climate change and knowledge on climate change adaptation, since create the flexible changes in the protection of environment of the community

- ✓ Organize the effective prevention of epidemic, particularly the tropical diseases.

5.4 Solutions for climate change adaptation option for Thuan An Town

5.4.1 Constructional solutions

- ✓ In order to minimize the effects of natural disasters and climate change phenomena, the local authority and people have had efforts in consolidating and newly building structures in the town including:
- ✓ Thao Long Dam was built in Dien Truong Village with the aim to prevent saline from lagoon coming to rice field and going upstream the Huong River as well as flood in flood season.
- ✓ In 2003, additional Dien Truong boundary dyke connecting National Highway 49A to Quy Lai dyke to prevent salinity from shrimp pools in Tan My and Dien Truong coming to the entire agricultural area in Phu Thanh and Dien Truong was built. Up to now, only about 400m of this dyke was built.
- ✓ At about early XIX century, the H character dam had been built at Thuan An Estuary to prevent salinity and flood. At present, a part of this structure has been submerged due to some people took away a part of its materials; the rest part creates Hai Tien Bay for fishermen mooring their boats and ships to avoid typhoon and for preventing the runoff flood pouring out from the Huong River. This part is about 500m long in Hai Tien Village, and called Hai Tien Stone Road. Presently, some households live along this part.
- ✓ Beside Thuan An Estuary is Hoa Duan Strait of Minh Hai and Hai Thanh. In the food of 1999, this strait was broken and the sea water penetrated into lagoon, causing damages to houses of 64 households. These households had to evacuate to resettle in Lanh Rong. After that Hoa Duan strait was filled up, now it is the part of national Highway 49B going through villages Minh Hai and Hai Thanh. At present, the residents in villages Minh Hai and Hai Thanh had returned to settle down and this area has been built to become a tourist beach with verdant eucalyptus forest which was planted five years after filling up Hoa Duan Dam.
- ✓ The typhoon warning station at Thuan An Estuary was built in 2000. Thuan An border guard post sends typhoon warning to fishermen on the sea by signal fire and also by portable radiotelephone. At about 300m from the typhoon warning station is the lighthouse of 12–13m high in Hai Duong Commune (near Thuan

An), built in 2001. When there was not yet the lighthouse, the people use the flag pole in Tan Lap Village of about 5–6 m high to hang a flashing red light for both typhoon warning and guiding fishing boats. These two structures are under the control of the Thuan An border guard post.

- ✓ Thuan An fish port, Bau Sen Dock in An Hai, Tan Binh and Tan Lap Docks as the shelters for boats and punts of Tan Binh and Tan Lap Villages should been upgraded.

5.4.2 Non-constructional solutions

5.4.2.1 Make use of local knowledge on weather and climate

- ✓ Almost all local knowledge is experience which the people has drawn from activities of production and living and disseminated from generation to generation. The people of Thuan An makes use of local knowledge on the coming changes of weather and the repetition of the extreme phenomena to strengthen the capability of adaptation in the process of responding to natural disasters.

5.4.2.2 Strengthen the capability of enduring

- ✓ In activities of production and living, Thuan An residents create by themselves various measures to adapt and prevent against natural disasters.
- ✓ Houses in depressed areas or near to lagoon, river bank and seashore often have high and solid foundations; the temporary houses in areas for fishing aqua-products are only made of cheap materials for easy evacuation to higher areas. Almost all families have boats and life buoys in case of flood.
- ✓ The netting activities of fisherman are in accordance with seasons and periods, suitable for climate seasons and changes of tide. The fishing on the sea is mainly from March to July and on lagoon is often at night, the most active activities are from March to May…
- ✓ Almost all people in the area should be trained on swimming; children of 10 year old should swim well already

5.4.2.3 Organization for natural disaster prevention and preparedness

- ✓ Thuan An Town has a flood and storm control committee chaired by the Town Chairperson with representatives from all sectors and four committees of wards for flood and storm control which are under the leadership of a commune officer or head of village.
- ✓ The members of associations, organizations and units of the armed forces are taking part in flood and storm control.
- ✓ The Town People's Committee is the focal point in activities of natural disaster management.

5.5 Solutions of climate change adaptation in Chan May–Lang Co area

5.5.1 Planning of reasonable land use

- ✓ It is necessary to have measures for protection of the seashore, plant protection forest; maintain sand dunes and coastal vegetation coverage; conserve the mangrove forest of the Bu Lu River.
- ✓ Stipulate separate area between coastal zone and construction area to be secure against sea level rise and natural calamity caused by climate change.

5.5.2 Research into design criteria

- ✓ Appropriate design criteria should be used, particularly foundation and roof for structures, pay attention to water drainage, especially in urban and industrial areas.
- ✓ Development and application new criteria of design and construction of coastal structures, sea dyke and sea port to take precautions against the sea level rise of 1m to the year 2100.

5.5.3 Other solutions

- ✓ Protection coastal forest and mangrove forest, options for effective prevention of forest fire.
- ✓ Protect Lang Co and Canh Duong beaches before the dangers of collapse and erosion…
- ✓ Enlarge Lang Co Estuary; dredge narrow passages of harbors
- ✓ Build planning of typhoon shelters for boats, ships and for coastal residents. The fishing on the sea will be reorganized.

- ✓ Raise public awareness and capacity in adapting to climate change
- ✓ Develop and operate the climate change observation, monitoring system in the area.

5.6 Integration climate change consideration into ICZM

5.6.1 ICZM strategy

The ICZM strategy for Thua Thien Hue province reflects the willingness and commitment of the provincial authorities and people to carefully balance interests with respect to the protection and the use of coastal resources and environment for the sustainable development of the coastal zone.

5.6.1.1 Scope of the strategy

Scope of the strategy: In compliance with the concerns and capacity of the stakeholders in Thua Thien Hue, the strategy focuses on the coastal part of the province, which includes the strip of coastal plain and sandy land, the Tam Giang – Cau Hai lagoon and coastal water of the province up to 40m deep, in 6 districts, including Phong Dien, Quang Dien, Huong Tra, Huong Thuy, Phu Vang, Phu Loc and Hue city.

5.6.1.2 Objectives of strategy

- Minimize environmental pollution and degeneration of natural resources, especially aquatic natural resources and biodiversity

- Prevent natural disasters; minimize natural disaster effects, support poverty alleviation, improve material and spiritual life for resident community.

5.6.1.3 Content of the Strategy

1. ICZM capacity building
2. Common resources and environment protection
3. Mitigation of impacts from and damages by natural disasters
4. Sustainable use of the coastal natural resources

5.6.2 Integration climate change consideration into ICZM

The document of strategy for ICZM was promulgated in the National wide level in 2003. The strategy of ICZM agrees with the strategy of adaptation to climate change in the approach, methods of implementation and objectives of environment protection for sustainable development.

However, in process of the preparing of the strategy of ICZM, it has not yet considered the changes in climate as well as their impacts on natural conditions of this area. Therefore by provincial stakeholder opinion, it is necessary to integrate some solutions of adaptation to climate change into important contents of strategy of ICZM including:

- Raising management capacity for ICZM in affected by climate change condition. Raising awareness and knowledge on disaster in future causing by climate change and adaptive measures for ICZM to respond to climate change for community, local government authority and policy makers.

- Re-development the coastal zone management framework protocol and action plan in administrative system of Thua Thien Hue towards in direction of sustainable development, harmonious sector benefits and adaptive to climate change.

- Re-recognize the areas, fields and communities most vulnerable by climate change impact, identify effective measures to maintain the sustainable development for these specific zones.

- Re-assess the bearing capacity of coastal zone and lagoons and potential adaptive capacity of the sectors: agriculture, aquiculture, tourist and industrial development in the coastal zone.

5.6.3 Activities to be taken:

5.6.3.1 At the provincial level:

- Provide updated information of climate change impact on human and socio – economic development in coastal zone.

- Measures for Thua Thien Hue province to mitigate impacts of climate change when implementing ICZM strategy:

(1) Good knowledge on climate change,

(2) Promulgate adaptation policy,

(3) Promulgate policy for sustainable exploitation and usage natural resources considering climate change disasters,

(4) Setup climate change adaptation plan of actions,

(5) Encourage investment in low GHG emission industry, prevent deforestation for GHG reduction.

5.6.3.2 At districts and commune level:

- Awareness raising on the harmful effect of climate change.

- Protect dike to avoid land slide, overflow.

- Implement climate change mitigation policy and sustainable exploitation and usage of natural resources policy.

- Development and implementation commune plan on disaster protection

5.7 Implementing Adaptation

How should these be implemented in practice? Province can not do it alone. Adaptation measures to climate change are and will continue to be implemented primarily by communities, the private sector, and individuals. But the role of provincial Authority will be essential in mainstreaming adaptation into policy and development planning, in creating partnerships with communities, non-governmental organizations (NGOs) and the private sector, and in dealing with problems only the government can handle (such as disaster management, ICZM strategy).

These messages that could be rise in discussions as well as in workshops/interviews meetings with local policy makers. They were included in some awareness-raising or training/recommendation booklets for this group.

To the question “Why we have to take into account climate change issues in policies and decision making? Why policy level intervention is important?”

- This is an actual global trend that all countries have to comply
- Climate change could “bring” the money and opportunities
- It could bring new knowledge and technology
- It could help reduce the losses
- People may know better how to adapt, but they need the guidance and good organization
- The poor, the elders, women and children are more sensitive
- Knowledge and experiences are power

- From micro- to macro-adaptation, from local to national and regional
- We need quality intervention in policy making and planning
- Combination of top-down an bottom-up approach is the best way.

In global context, the climate change issues, its impacts and adaptation became a hot pot for policy making process in most developing especially in Vietnam now. It became a part of the compliance of international Conventions and agreements on global climate and environmental problems as UNFCCC, Kyoto Protocol that Viet Nam has ratified and signed.

Thus, taking into account a climate change problems, its impacts, future trends and uncertainty factor as well as mitigation and adaptation mechanisms in the policy making process could open new opportunities, financial, technical and technological support for Vietnam from all over the world.

That would also bring into the policy development and implementation process the new scientifically based knowledge and arguments, new approaches of pro-active preparedness and prevention rather than passive response to the problems or recovery aftermath, with the view to future scenarios and trends. In the future, when the adverse impacts, extreme events or disasters really occur, it will help in coping and relief activities, mitigating the damages and losses of property and human lives.

Until certain extent, people have always been trying to respond and adapt themselves to the climate variability and changes, the extreme weather events and disasters. However, in case of stronger, larger or more severe disasters, they would usually expose their lives and properties to high risks and dangerous impacts, their responses may become chaotic, scattered and inefficient.

The most vulnerable to all types of impacts and dangers are always the poor people and special sensitive contingents: the elders, the women and children. In critical or disaster time, they may some time be paid less attention or even forgotten. That why many disaster casualties (especially the floods and storms) in Viet Nam belong to the elders, women and children. In that case, they need very much well organized help and guidance, concrete and urgent measures from local, provincial and central authorities in relief and rescue works, after-disaster aid and recovery. Moreover, they need to be informed, early warned about the events, and good trainings for different types of impacts.

Needless to say how important are awareness, knowledge and capacity of policy makers, authorities and managers at all levels in:

- Rising awareness and understanding the present and future problems and impacts for the local people;
- Leading, guiding and helping them to deepen into those problems, to take actions for coping with and adapting to climate change impacts and disasters;
- Good theoretical and practical training for local communities for proper and timely preparing to all kind of different disasters and every particular event.

The policies need to be made for the people interest of safety and prosperity, but at present are not yet in such condition so far. We definitely need quality intervention in the policy making, planning and managing processes at all levels of authority.

In the other hand, in such a highly disaster-prone province like Thua Thien Hue of a disaster-prone country like Viet Nam, people always have experiences and empirical knowledge for hundred years in adapting to and coping with climate related impacts and "usual" extreme events (typhoons, storms, flood and drought), in their particular locations and they obviously have very good ideas. By these reasons, the adaptation processing has to be done firstly at local levels as "micro-adaptation", with local knowledge and special characteristics, only then at broader, "macro" scale: provincial, national levels.

International experiences show that good combination of top-down an bottom-up approach of decision making, where local people's knowledge, opinions and experiences is discussed and considered, is the best way to effective adaptation to climate change. this is achieved in this study in Thua Thien Hue.

The results of stakeholder participation in process are given in box 5.1.

Box 5.1

Summary results of investigation and stakeholder interview on "Integration of climate change consideration into social-economic development plans, strategy as ICZM"; Total number stakeholders-representatives for different sectors, communes: 50 (43 males and 7 females)

Findings:

1. Almost all interviewees think that climate change has led to phenomena such as sea level rise (88%), and more natural disasters: whirlwind, flood, more frequent heavy rainfall and drought (98%), collapse and erosion (96%), lack of water (84%) and the silting up of riverbank and seashore (75%). While the phenomena which many people consider the most frequent ones caused by climate change are typhoon, whirlwind and flood. However, only 2/50 number of people find that the collapse and erosion of seashore are the phenomena which they most frequently meet with among the ones caused by climate change.

Apart from that, according to several people, climate change can also lead to the following phenomena:

- Abnormal weather, temperature goes down in winter and goes up in summer,
- Changes of flow, weaker runoff
- Forest fire,
- Desertification,
- Snowstorm,
- Extinction of some living creatures,
- More occurrences of epidemics,

2. Information on climate change comes from various sources including radio, TV, training courses, workshops and self recognition. Some people know about them by other sources such as internet, specialized magazines, newspapers, poster, books and local circular letters or from their research results.

3. More than 88% of interviewees said that climate change has led to more inundation in rainy season, and more lacking of water in dry season. The effects of climate change caused more difficulties for agricultural production, so they had to change crop season. There were from 34 to 37 people thought that the productivity of fishing and cultivating aqua-products decreased due to climate change effects and led to the lack of food. Houses and resident areas were more threatened. Moreover, many people found that human and animal health were also much affected by climate change. In the above-mentioned effects, the inundation in rainy season is the most obvious one.

4. All sectors are affected by climate change but the most seriously affected is agriculture.

5. Climate change has impacts on weather leading to the appearance of many viruses and bacteria that cause new and more complicated infectious diseases which happen more frequent on large area as follows:

- Diarrhea, digestion disease

- Flue and respiratory diseases

- Diseases of ear, nose and throat such as sinusitis

- Skin disease

- Cardiovascular disease, high tension.

Especially the infectious diseases are more complicated and happen on large scale, mainly for old people and children. They also lead to tiredness and decrease of the resistance.

Only one among 50 people has not yet found the effect of climate change on health.

6. There were 47 among 50 persons thought that human beings can mitigate climate change

7. In order to mitigate climate change, the necessary measures are: reduce GHGs emissions in production, save fuel and electricity, plant forest and do not burn forest.

Some other measures were also mentioned:

- Educate awareness to adjust human behavior

- Use clean energy, use biogas

- Re-planning of the professions of production in reasonable way

- Use the easily decomposed products that are friendly to environment, apply techniques to recycle wastewater

- Exploit minerals in scientific ways with inherited restoration

- Environment protection.

Among the above-mentioned measures, the measures of “GHGs emissions reduction” and “do not burn and destroy forest” are considered the most effective ones in mitigation of climate change.

8. In order to respond to climate change, the interviewees have chosen various methods such as construction of waterworks, structures to protect the seashore, evacuation, consolidation of public works, use and dissemination of local knowledge in natural disaster prevention and preparedness. Among them, the method which are most selected by people is use and dissemination of local knowledge in natural disaster prevention and preparedness (more than 50% interviewees).

Many other interviewees thought that it was necessary to disseminate and raise the knowledge on climate change for all people.

9. In order to adapt to climate change in Thua Thien Hue, many people agreed with 7 measures:

- Climate change knowledge and awareness raising,
- Development of plan for adaptation, deploy the ICZM strategy,
- Hydropower projection,
- Development of integrated action plan for natural disaster prevention and preparedness,
- Effective management and use of water resources,
- Strengthen health and capability of preventing diseases.

10. More than 80% of the interviewees agreed with 5 solutions for provincial level to mitigate climate change. These are the understanding about climate change, promulgate policy on mitigation, promulgate policy on exploitation and use of natural resources in sustainable way, development of plan for implementation the measures of prevention and preparedness and raise the commune awareness on climate change. Moreover, some other proposals for provincial level are following:

- Encourage investment for industry with less GHGs emissions
- Have policy to control GHGs emissions
- Educate the people do not destroy the protection forest
- Invest for building stone embankment to prevent collapse and erosion
- Organize awareness workshops on climate change.

The solutions put forwards to district, communes and households are agreed upon by majority, particularly for households, every citizen was advised that:

- It is needed to have consciousness in using national resources
- Take part in planting coastal forest, protecting forest and waterworks
- Restrict the use of various kinds of fossil fuels and products that emit GHGs
- Find the suitable practice of production to adapt to climate change,

- And self protect family health.

11. There were more than 44 people agreed to support the integration of the adaptation to climate change into the mentioned fields. But the most priority is given to integration into local plan of socio-economic development.

12. The ICZM strategy is well known for most stakeholder-interviewees. They knew it through various sources of information, but mainly through the project document, workshops and training courses. They are good aware of the objectives of the strategy and they show a good position on supporting of integration of climate change consideration into implementation of ICZM.

13. Some advantages of the sectors in the process of implementing ICZM strategy include:

- Awareness, capacity and qualification of officers working on natural resources and environment are good

- There are modern equipment and technology for management

- Having a good experiences to work with fishermen and aquaculture people

- There is good data base of the data and information on the coastal zone and lagoon

- The high agreement from stakeholders

- There is a good coordination in activities of the different sectors and local authorities

- Good experiences the in implementation of previous phase of ICZM.

14. There were 43/50 interviewees fully supported the integration of climate change into ICZM and 6 people partly supported. Almost stakeholders support to integrate climate change consideration and adjustment the ICZM strategy reflecting the climate change conditions and impacts.

There are many ways of supporting the integration, but the most obvious ones are taking part in contribution of opinions and campaign for raising awareness. Many people think that these are necessary so they willingly participate in. Moreover, some individuals/units may mobilize the support from other people such as family, friend, colleagues, the Youth Union and households. Some people support the integration with the following conditions:

- Reasonable contents and plans of integration

- Equipped with complete knowledge

- Can participate in programs and projects

- Get the financial support.

15. The departments, boards and individuals that are considered as those would support the integration of climate change information into and revision of ICZM are comprised of:

Provincial level:

- Provincial People's Committee

- Department of Agriculture and Rural Development

- Department of Natural Resources and Environment.

District level:

- District People's Committee

- Section of Natural Resources and Environment

- Section of Agriculture and Rural Development

- Department of Science and Technology

- Department of Tourism

- Center for Meteorology and Hydrology

- Branch Department of Flood and Storm Control and Management of Dyke.

Commune level: All officers and Boards of communes.

16. Organizations/individuals that may protest against the integration include:

- Industries, construction

- Economic units

- Titan ore companies

- Cement production Company

- Wood exploitation Company

- Individuals who are working and earning by professions of forest and coastal sand exploitation.

The reasons of their protest are:

- The integration may affect their profit in business
- The integration may restrict their exploitation of natural resources
- May make them pose to the danger of violating the laws due to the pollutants to environment
- May cost money and time

In order to respond to climate change, every body should:

- Provide and update climate change information in locality from the mass media
- Regularly consider whether their activities of production have effects on environment and climate,
- Have attitude of cooperation with local authority, carry out the common regulations on protection of environment and weather
- Prepare necessary conditions to deal with different types of national disasters in order to protect the life and property of oneself and family
- Implement ICZM with integration of climate change information
- Mobilize and remind one another and together protect natural ecological systems and environment
- Reasonable use and saving of natural resources and energy
- Reasonable exploitation and use of natural resources without polluting the environment
- Plant forest on the coastal area and bare hills, prevent forest from fires
- Find the way and measures to live together with climate change and measures of natural disaster prevention and preparedness
- Promote health and capability of preventing diseases
- Use local knowledge in natural disaster prevention and preparedness

Compiler of the report

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CHAPTER 6
LESSONS LEARNED AND RECOMMENDATIONS

6.1 Cost-effective use of local and existing resources and decentralization

Maximal and creative using of all possible local resources and existing results of the past or on-going studies and projects was a priority focus of this project. Although the time frame was prolonged, with such a limited budget, the project implementer – the IMHEN – could have implemented a variety of tasks: conduct the climate change impacts assessment for water resources at river basin scale, downscale climate change scenarios for a limited area, conduct climate projection and hydrological modeling, carry out the participatory studies, assess the local adaptive capacity, consider the adaptation measures for different levels: the province, the district and a concrete commune. All of the initial targets were reached to varied but certain extent.

Such results could be achieved only with the proper mobilization of local sources, including information and data, technical, financial and human resources, especially the results and collaboration from other activities and projects. Last point will be considered further in the second lesson.

6.2 Cost-effective collaboration

Closed collaboration of relevant development projects in the same area/sector or with the similar goal/targets should be encouraged to avoid overlapping works and maximize the use of information, technical sources, connection and network, financial and human resources.

In the first phase, two meetings were organized with representatives of different projects in Thua Thien Hue and especially in Phu Vang district (including IMOLA, ICZM, FAO, CECI, PVC, Kyoto University and ABD, etc.) where the participants have shared information and experiences, connection and networks. All the participants have acknowledged the importance of such sharing and collaborating mechanism. However, as they also recognized, most of the projects were still working separately, almost no budget and resource allocated to the collaboration. Besides, there are many constraints for the effective collaboration, such as lack of concrete mechanism and resources, bureaucracy of some local structures etc.

There must be established a special unit for coordination of those activities with small but certain budget allocation, possibly independent from the local government. Up to now, such a body was not established yet, so one of the recommendations is to encourage all the projects' donors/investors to allocate certain amount from the project budget to the so called "collaborative fund" for this important and possibly very cost effective mechanism

6.3 Use both top-down and bottom-up styles in participatory approach

The local people, especially the poor are most vulnerable who will immediately and fully bear the impacts but also the beneficiaries at the same time, so they need to be involved in the process of adaptation at all stages, from the very beginning of project development to the monitoring and evaluation of the project outputs. Therefore, the bottom-up approach is essential in designing practical adaptive measures with local context and specificities, and in small scale adaptation and intervention projects.

However, this approach could not fully work with the more strategic project aiming to policy making and intervention. In this case the approach should be combined to ensure effectiveness and benefits

6.4 Need for translation of the scientific studies results to the language of the end-users

One of the most difficult but important tasks is to translate the scientific results to the easy-to-understand language for the different target groups: the provincial leaders and policy makers, the sectoral managers and local authority; the local communities and poor people.

The local people would not talk in the same language as the experts, and they don't like complicated scientific issues, so all the results should be simplified and correlated with local/regional customs and problems.

In the other side, the policy makers and authority would need concrete reliable evidence and numbers, data and facts which should be related with their political or economical interest, with shorter term decisions and plans and they would not like to talk about abstract idea or long term issue.

The long term climate change can usually be misunderstood by the local community and authority, they may not know that what they are doing every day may already be the so called autonomous adaptation measures. The task of the expert and project team is to improve their awareness and knowledge, which may lead to concrete positive actions

6.5 Wise use of indigenous knowledge and expert opinion

The local people know better regarding their needs and fear, where are more vulnerable areas, economic or livelihood sectors in their location but they need the technical support and objective view from-outside of the experts.

The local people may sometime get confused in the concept, knowledge or even measures, for example between mitigation and adaptation, so some clarification and capacity building is usually needed.

In the process of project implementation, many new ideas and facts could be explored and disclosed while working with local people, or authority. Sometime the experts may not right if they didn't in prior consulted with the local communities, but while they get the full picture, some creative and innovative solutions could be provided, which may change even the implementation direction or outputs. In this case, the purpose and overall objectives of the project should remain but some of the concrete objective or outputs could be changed or re-orientated in the process of project development to fit the practical reality.

6.6 Think globally, act locally

Adaptation to climate change should be linked with the global context and trend, knowledge, technologies and financial support, experiences and know-how from the international community can bring benefits and opportunities to the local people, like in the case of NCAP project for Thua Thien Hue province.

However, adaptation to climate change should be started from the everyday life activities and measures, from changes in knowledge, attitude and behavior and must focus more on near-term target to adapt to climate variability and disasters, address concrete local development problems.

6.7 Recommendations

Despite its priority to achieve accelerated economic growth, the Vietnam Government acknowledges that controlling and reducing the consequences of climate change and disasters are also key priorities. Activities to respond to climate change would have to be carried out systematically and in consistence with other activities/strategies of sectors and regions, especially in economic development plan of the whole country as well as within one province like Thua Thien Hue.

The results of the project should be used in mainstreaming climate change adaptation into the provincial socio-economic development plan, as well as to the ICZM action plan of Thua Thien Hue province which should be revised in 2009. Some difficulties were appeared in the policy making mechanism and administrative processes during efforts of the project team to word this integration. However, with the increasing awareness of the Government of Vietnam about climate change impacts and risks and the on-going process of preparation of the National Target Program to Respond to Climate Change (NTP), which is also led by the IMHEN and MONRE, the integration process will come to the provincial level very soon.

Bellow are proposed some specific recommendations for the most vulnerable sectors – agriculture, water resources and coastal areas of Thua Thien Hue.

6.7.1 Adaptations options for agriculture and rural development

- Change the crop pattern, domestic livestock at high risk areas, switch the area with low effectiveness of rice production into aquaculture; Define and re-arrange crop season, implement the suitable technical practices for each crop plants.
- Use of crop varieties which could overcome waterlogged, drought and extreme weather condition.
- Reorient the 5 millions hectare forestation program towards focus on upstream protective forest, coastal protective green belt and mangrove, to develop win-win solution.

6.7.2 Adaptations options for water resources, disaster prevention

- Develop and implement the integrated water resources management plan for the province considering climate change impacts and increasing water demand
- Improve the water regulation, flood protection system, dyke, irrigation, dams and reservoirs in order to protect and exploit the cultivate areas effectively.

- Develop and improve the disasters management, search and rescue plan for vulnerable locations;

6.7.3 Adaptation options for coastal and lagoon area

- A adaptation framework should be established for the coastal zone and lagoon area which should have purpose to: preventing loss of lives and property; avoiding development in disasters-prone areas, and ensuring that critical coastal ecosystems, such as wetland ecosystem or coral reefs, are protected and remain functional. Specific adaptation options could include:
- Good practical management of ICZM strategy with consideration on climate change information and it's impacts on sustainable development of the coastal zone
- Protection populated areas: Construction of sea dyke is the measure of choice to prevent erosion in densely populated coastal areas. However, sea dyke do not resolve the underlying cause of erosion, and they can promote offshore movement of beach sediments. They are also costly to build and maintain, and they will need to be extended as the sea level rises. Seawalls should be used only to protect valuable property and buildings that cannot be relocated. For new infrastructure, the use of setbacks and relocation could be considered.
- Land use policies: Land use policies should encourage settlements away from low-lying and high-risk coastal areas through, for example, the use of coastal hazard mapping.
- Prevention of erosion: Depending on the infrastructure and population density, adaptation options to prevent coastal erosion include (i) no response, where there is little habitation or infrastructure; (ii) accommodation, where property is replaced as it is damaged; and (iii) shoreline protection, in areas with large populations and significant infrastructure. In low lands, where it is essential to retain over-wash sediments, and other coastal vegetation to promote shoreline accretion, closing or narrowing selected passages between the lagoon and the ocean, and the strategic use of groynes to help minimize the transfer of sediments from the ocean side to the lagoons. Sea dyke, however, should be used only in key locations, such as the passage edges, as they tend to cause

downstream erosion and require continuing maintenance. In less developed areas the use of setbacks to control future development, beach nourishment and relocation of infrastructure might be preferable.

- Protection against inundation: On areas with little infrastructure, the costs of protection are likely to be prohibitive, and relocation or modification of structures to accommodate surface flooding could be considered. On the more populated strategies to allow over-wash sediment to naturally increase the elevation of the coastal may help offset the impacts of inundation. Where land ownership disputes are not an issue, new structures should be set back from the shoreline and elevated to allow for periodic flooding.
- Population relocation: If all other measures fail, population relocation may need to be considered. While some communities may opt to move on their own, population relocation would pose immense social and political risks for Thua Thien Hue governments, as nearly all inhabitable land is under some form of customary ownership.

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