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

Le Nguyen Tuong, Tran Mai Kien, Tran Thuc and Tran Quynh

1. Introduction

Located in Southeast Asia, with a tropical monsoon climate and a coastline of more than 3,260km, Vietnam is one of the most disaster-prone countries in the world. Most of the disasters that occur in the country are related to weather and climate, and consequently climate change and climate variability are likely to pose increasing threats to Vietnam and its inhabitants in the near and long-term future.

Climate change is not only an "environmental" issue; it already poses a wider threat to the sustainable development of Vietnam, having impacts on all sectors and regions of the country. In fact, the potential impacts of climate change on Vietnam are considered to be a very serious challenge to national efforts towards hunger eradication, poverty reduction and sustainable development. The sectors most vulnerable to climate change have been identified as: natural resources (water, land, and biodiversity); agriculture and aquaculture; energy; transport; and public health.

According to a recent assessment by the World Bank Vietnam is among the five most vulnerable countries to the impacts of climate change and consequent sea level rise. The strongest impacts are likely to be experienced in the low land delta (the Mekong River delta in the south and Red River delta in the north) and coastal areas. With a projected sea level rise of 1m by 2100, about 10% of the Vietnamese population would be directly affected and GDP would decrease by the same percentage. If the projected changes come to pass, approximately 40,000km^2 of the coastal areas and deltas would be inundated every year, including the complete swamping of about 80% of the Mekong River delta's area.

Even though more and more people are starting to become aware of the potential threats posed by climate change, climate change is also a relatively new and complicated challenge, which may cause short-term impacts and enormous potential risks and uncertainties in the future. Although the people of Vietnam have thousand year old traditions of confronting and overcoming a variety of natural disasters, identifying adaptation options to climate change at different scales may require new approaches.

It is in this context that the Institute of Hydrology, Meteorology and Environment (IMHEN) and the Department of Natural Resources and Environment (DONRE) in Hue developed and implemented the project 'Climate Change Impacts in the Huong River Basin and Adaptation in its Coastal District Phu Vang'. The project was part of the second phase of the Netherlands Climate Assistance Program and took place from 2005 to 2008.

The main objective of the project was to strengthen the capacity and preparedness of the different sectors, organizations and people in Vietnam to adapt and respond to the changing climate. A particular focus of the project has been on water resources and hydrology at the basin level, as well as a deeper investigation into adaptation issues at the local level. Thua Thien Hue Province, the Huong River Basin and Phu Vang district in Vietnam were chosen for this pilot study. Through this, the project also tried to contribute towards the implementation of Vietnam's national strategy for poverty elimination and sustainable development. The results and findings of the project may be further analyzed to develop a participatory climate change adaptation and integrated water resource management model, which can be used in other basins and areas nationwide.

Specific objectives of the project were:

- To combine water flow modeling for an entire river basin with participatory management tools for a coastal district or village.
- To study existing and future climate change impacts on water resources in the river basin and understand how poor people's livelihoods depend strongly on climate and water resource changes.
- To improve awareness, a proactive attitude and preparedness regarding climate change and its impacts among all related stakeholders, especially the local authority and policy makers and the most vulnerable communities.
- To understand local customs and indigenous knowledge regarding weather, climate and disasters and assess and improve existing adaptation measures with stakeholders' participation.
- To prepare and develop, with stakeholder participation, the optimal feasible adaptation plan and policy at district level with a view to replicate them at provincial and national levels.

The remainder of this chapter will provide an overview of the background and approach of the project as well as some of the key results and findings in Vietnam. As it is not possible to present all the results and findings in this chapter, the reader is referred to the various technical papers for more information on specific aspects of the project. The chapter will end with a short summary of recommendations and lessons learned.

2. The study area and methodological approach

2.1 The study area: Thua Thien Hue Province, Huong River Basin and Phu Vang district

Thua Thien Hue (TTH) is a province in the coastal zone of northern central Vietnam, located between 15059'-16048'N and 106025'-107051'E. It is bordered on the east by the East Sea of Vietnam (South China Sea) and on the west by Laos (figure 1). The province has a varied geography including forested mountains and hills, rivers, streams, (rice) paddy fields, coastal lagoons and marine areas. Lying on the east–west corridor connecting Myanmar, Thailand, Laos and Vietnam with the South China Sea, Thua Thien Hue is one of four provinces of the Central Key Economic Zone and is one of the most famous cultural and tourism areas of the country.

Thua Thien Hue has an area of 5,053km^2 and is divided into nine administrative districts. In 2006 the population of the province was estimated at 1,150,000 inhabitants, with about 300,000 of these living in or around the ancient capital of Hue. Much of the province's infrastructure and industry lies in the coastal plain and most of the population lives within 25km of the coast. As such, Thua Thien Hue is at high risk from disasters and other climate change-related impacts.

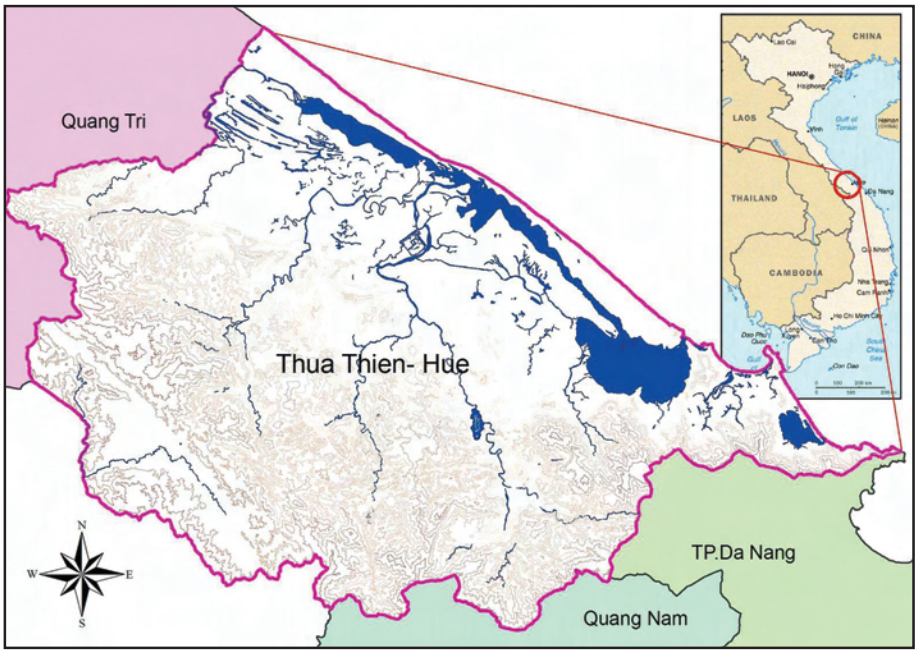

Figure 1: Location of Thua Thien Hue Province in Vietnam and the Surrounding Regions

The *Huong River Basin* is the largest basin in Thua Thien Hue Province. It has a length of 104km and three main tributaries: the Ta Trach, Huu Trach and Bo Rivers. The total area of the basin is approximately 2,830km^2, among which more than 80% consists of mountainous and steeply hilly terrain (the average basin altitude is 330m and the average basin slope is 28.5%). The Huong River Basin is located in the specific monsoon climate zone of central Vietnam with a severe meteorological regime: a long dry season followed by a short rainy season with often very intense rainfall. Almost all of the record rainfalls measured in Vietnam have been in the Huong River Basin. The highest rainfalls on records are in Thua Thien Hue: daily – 731.3mm, monthly – 2,451.7mm and annual rainfall – 5,910.7mm.

The Huong River Basin contains a unique ecosystem of national importance – the Tam Giang-Cau Hai lagoon, which is the largest lagoon system in Vietnam and in southeast Asia. 24,876ha of the Tam Giang-Cau Hai lagoon were included on a list of 16 proposed wetland and marine protected areas in Vietnam in 1998. However, due to the changing environment and poorly planned expansion of the aquaculture sector, the ecological integrity and water quality of the lagoon system has rapidly degraded. In addition, construction of a major anti-salinity weir in the Huong River is decreasing downstream freshwater flows and is impacting on the fauna and flora in the lagoons.

The Huong River is also the main source of irrigation water for agriculture and aquaculture, provides the water supply for industry, energy generation, municipal and civil use, and supports the existence of various ecosystems and wildlife on a large scale. Consequently, demand for its water is very high. In addition, there is dense human settlement in the Huong River plain and coastal area, with the majority of the population living near the poverty line and whose livelihood strongly depends on the river basin's natural and water resources. The seasonal distribution of water resources in the basin is not consistent. Very high discharge in the rainy season causes flooding and inundation whilst low flow in the long dry season often causes a water supply crisis. Potential impacts of climate change and consequent water demand pressure would only exacerbate such crises, increase water pollution and saline intrusion and contribute towards ecological and wildlife degradation.

Phu Vang is a coastal district in the lower part of the Huong River with a diversity of landscapes: mixed low-lying agricultural land and aquaculture ponds cover the river estuary and part of the above-mentioned Tam Giang-Cau Hai lagoon. Phu Vang is among the most vulnerable districts in the province, bearing the burden of untimely pressure from both the ocean (typhoons, storms, sea level rise and saline intrusion) and the river (flood and drought). The low level of local people's awareness and their very limited sources of income, along with their unwillingness or inability to resettle, all contribute to the huge loss of human lives and properties in the case of a large storm or flood. In the 1999 flood, 64 households of Hoa Duan village located in the lagoon were washed out to the sea and hundreds of people died or remain missing.

Since ancient times, Thua Thien Hue Province and the Huong River Basin have been recurrently affected by many types of climate-related disasters such as typhoons, storms, floods, droughts and landslides. Recently, such disasters have increased in both frequency and intensity, causing significant socio-economic turbulence and loss of life, seriously damaging upstream and downstream infrastructure and ecology, impacting on World Heritage Sites and destroying people's livelihoods and properties. Table 1 summarizes the enormous losses in Thua Thien Hue Province caused by recent severe flooding events in October 1983, September 1990 and November 1999.

Table 1: Flood-related losses in Thua Thien Hue Province, Vietnam

No	Losses and Damages	Oct 1983 Flood	Sept 1990 Flood	Nov 1999 Flood
1	**Number of people dead/missing**	30	5	127
2	**Rice paddy** Damaged/inundated subsidiary crop area Damaged industrial crop area Fields swept away/filled up	6,152ha 8,754ha 65ha 30ha	7,066ha 1,994ha 1,577ha 370ha	28,779ha 8,747ha 4,073ha
3	**Infrastructure** Collapsed houses Hospitals Irrigation structures: - Soil swept away - Stone swept away - Concrete Transport networks - Soil - Concrete - Damaged bridges - Electrical cable poles	 1,340 52 1.24 mil. m3 1,050m3 240m3 821,000m3 198m3 54 32	 735 91 1.29 mil.m3 1,265m3 151m3 742,000m3 285m3 55 35	 7,121 119
4	**Other properties** Sunk boats Dead buffalos/cows Dead domestic animals (others)	 915 425 heads 170,000	 270 heads 194,210	 1,645 heads 319,377
Monetary value (with USD approximates)		75 bill. VND (5.6 mill. USD)	120 bill. VND (8 mill. USD)	925 bill. VND (60 mill. USD)

Hue City and the Huong River are both World Heritage Sites and famous tourist destinations, providing income for an increasing number of local people. Protection and adaptation measures for

the Huong River system to help address negative changes are very important economically in the context of the above. To better preserve the world heritage and landscapes of Hue City, adjacent areas and the Huong River, it is not appropriate to build dykes along the river or an embankment system around Hue City and the historical sites, so flooding usually spreads across very large areas. In addition, the topography of the Huong River Basin changes rapidly from the upstream mountainous zone to the plains and large lagoon system, with hardly any transition area, resulting in high runoff/flow in the rainy season and extensive floods and inundations downstream.

During the dry season, the prolonged low rainfall causes salinity to intrude far upstream, badly affecting agriculture, lagoon ecology and aquatic resources. The saline intrusion can reach Bach Ho Bridge, more than 10km from the Huong River estuary, where the intake for Hue City's water supply system is located. Moreover, the upstream "slash and burn" cultivation practices and rapid deforestation together with the geographical and meteorological characteristics of the basin are causing more erosion, creating increased risk of land slides and flash floods in the mountainous areas (figure 2).

Figure 2: Climate Related Disasters and Environmental Change in Different Parts of the Huong River Basin

2.2 Methodology and activities undertaken

The project combined various stakeholder approaches with water modeling.

The technical tools were selected and deployed by the IMHEN on the basis of the need to provide reliable, scientifically-based results and evidence which could help in convincing local authorities, in raising awareness and knowledge and in designing adaptation measures.

Participatory tools have facilitated the involvement of local stakeholders in all stages of project implementation to ensure (a) the local context and practical usefulness of the project results and (b) that the demands and needs of the most vulnerable people are considered.

The chosen set of participatory management and technical approaches support the effective transition between stages in a project cycle, from research to decision-making and development of adaptation measures.

The following major activities were undertaken:

- Collection and analysis of data on meteorological and hydrological factors and natural conditions, as well as the administrative and socio-economic conditions of the study areas: Thua Thien Hue Province, the Huong River Basin and its coastal zone – Phu Vang district.
- Provision of climate projections and downscaling of regional climate change scenarios to the provincial scale.
- Assessment of the impacts of climate change on water resources by conducting water and hydrological modeling for the Huong River Basin with the help of MIKE 11, MIKE Basin and some other software.
- Collection and analysis of data on livelihoods and vulnerability to climate change and disasters of the poor people in Phu Vang district.
- Development and implementation of the stakeholder action plan (SAP) for the coastal zone, especially Phu Vang district and the most vulnerable commune in the district – Thuan An commune and Chan May–Lang Co – including stakeholder meetings; surveys and semi-structured interviews using PRA tools with different local and external stakeholders; technical workshops with key stakeholders; further guidance and feedback.
- Analysis and synthesis of the results, leading to proposed improvements of adaptation options and policy recommendations.

3. Key results and findings

3.1 Past trends and future climate projections

The project started with a number of studies in order to better understand the historic trends in climate conditions in the study area. In addition, downscaled climate scenarios were developed for the decades up to 2100. Some of the key results of these studies are presented below.

3.1.1 Historic climate trends

In order to understand the historic trends of the climate conditions in Thua Thien Hue, the study analyzed the variability, climatologically average, moving average and trend line of some key climate parameters, including rainfall and temperature. The rainfall was analyzed in 4 different periods of the year: January to March; April to May; June to July; and August to December. Temperature data was taken from January, April, July and October, typical months for the hot season, the rainy season and the two interchanges. The data was collected from three meteorological stations in Hue Province: Hue, A Luoi and Nam Dong stations.

The temperature of all typical months and the mean annual temperature at A Luoi and Nam Dong stations revealed an obvious increasing trend during the studied period (1974 to 2004). Annual rainfall at A Luoi and Nam Dong stations was very high in absolute value (about 3,500mm on average and up to 6,000mm in the peak years), and have significantly increased in the period 1974 to 2004 approximately 800mm and 600mm respectively.

The largest increase in rainfall occurred during the rainy season (August to December), months that were the major contributors to the total annual rainfall. June to July's rainfall at both stations has a noticeably decreasing trend. This indicates a high risk of prolonged drought during the important growth period of major crops as well as a risk of water shortages affecting power generation, especially at a time that the demand for energy is high during the hottest period of the year.

Figures 3 and 4 depict the trends in annual temperature and rainfall changes in the period 1974 to 2004 for different meteorological stations.

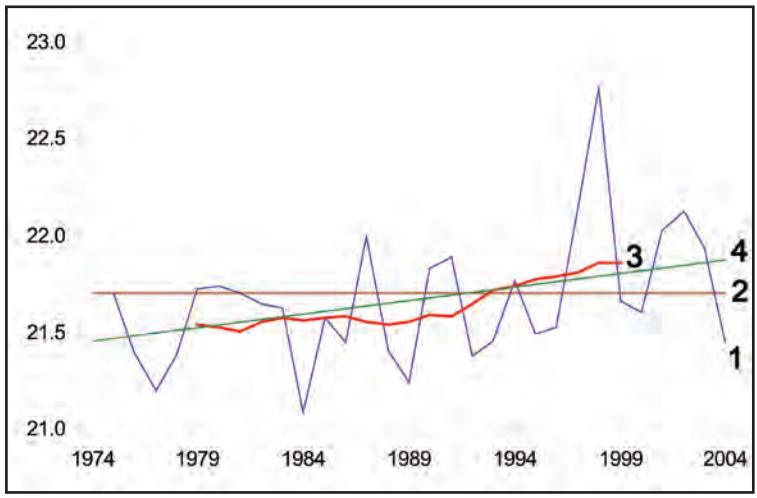

Figure 3: Variability (1), climatological average (2), moving average (time step – 11 years) (3) and linear trend (4) of annual average temperature at Station A.

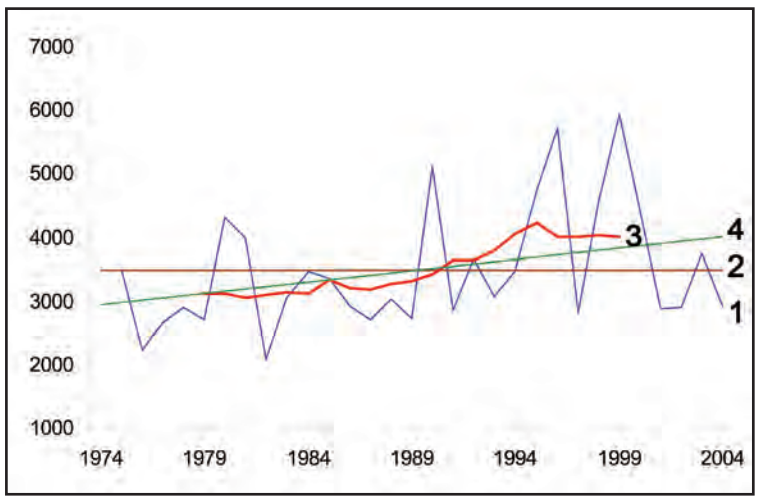

Figure 4: Variability (1), climatological average (2), moving average (time step – 11 years) (3) and linear trend (4) of annual rainfall at Station B.

3.1.2 Future climate change in Thua Thien Hue:

The development of climate scenario data is based on the 'Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment' published by the IPCC. Global and regional (Southeast Asia) scenarios were downscaled into the project area by using MAGICC/SCENGEN software.

The following basic sources of input and boundary data were used for developing the climate scenario:

- Results from Global Circulation Models (GCM) and Ocean-Atmospheric Global Circulation Models (OAGCM);
- The IPCC's global emission scenarios and regional climate change scenarios for Southeast Asia;
- Past trends of observed meteorological data for the last 30 to 40 years in Vietnam and Thua Thien Hue Province;
- Observed sea level data at stations and analysis from the Marine Hydro-Meteorological Center; and
- Experts' opinions, related literature, including influences of regional factors and ENSO on the climate of Vietnam.

Six different emission scenarios (2 High-, 2 Medium- and 2 Low-emission) for Thua Thien Hue were selected. The results of the downscaling represent the changes of rainfall and temperature in the province over the period 2010 to 2100 in comparison to the 1990 baseline for the different emission scenarios. Figure 5 shows an example of the downscaling results of temperature and rainfall for the Huong River Basin for the A2 scenario.

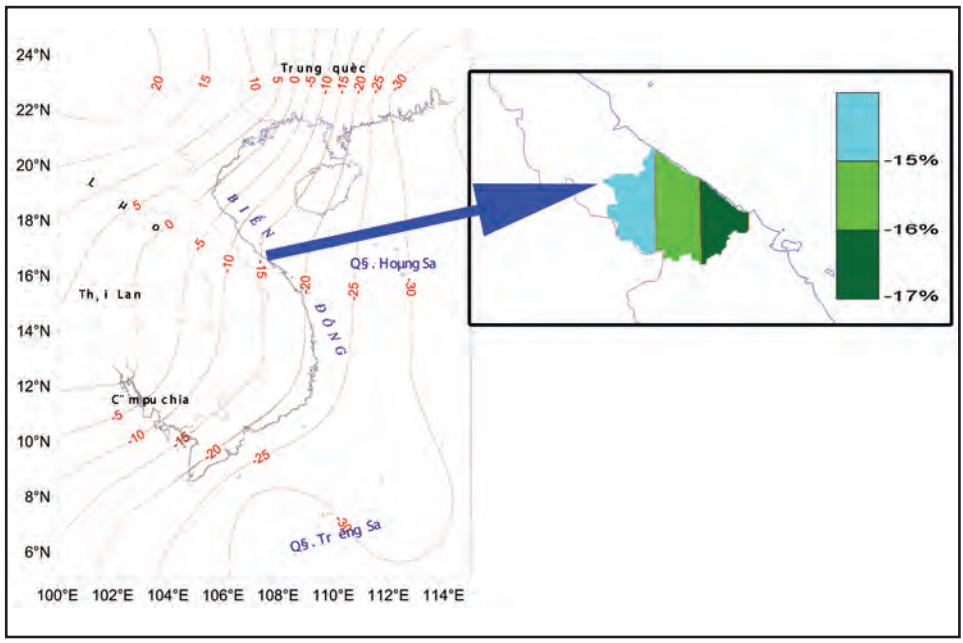

Figure 5: Example of downscaling from regional to provincial projection for Thua Thien Hue for Dec to Feb rainfall in 2100 in comparison with 1990, high emission scenario A2.

According to the model outcomes, the annual mean temperature is expected to increase by 2.5 to 2.6ºC by the end of the 21st century. The increase is more pronounced in January and February (2.6 to 2.7ºC) than in the hotter months of June and July (2.4 to 2.5ºC).

In the case of the high emission scenario (A1FI), the temperature would increase the most: by 3.9ºC on average, and in the March to May period a change of up to 4.7ºC may be experienced (see table 2). Such a high temperature increase may bring very serious consequences for socioeconomic and ecosystem wellbeing, especially for human health, but combined with a projected increase in extreme events (droughts, floods, storms, etc.) it may lead to catastrophe in Thua Thien Hue Province.

Table 2: Projected decadal increase in annual and seasonal temperature (ºC) in TTH from 2010 to 2100, compared with the 1990 baseline for 2 emission scenarios.

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

When it comes to annual rainfall, the model results show an estimated increase of about 7% on average. While the dry season of February to May is showing a decrease of 10 to 15%, rainfall is expected to increase significantly during the rainy season (September to November) by 10 to 24%. Rainfall in August – the first month of the rainy season – is expected to increase much less (2.5 to 3%).

In the "worst case" high emission scenario (A1FI), rainfall in the rainy season would increase by 25% whereas the first dry months (December to February) show a decrease of 23% (table 3). The most important aspect revealed is that rainfall in the dry season (December to February and March to May) is likely to decrease, which may cause very severe droughts. If this were to occur, severe drought would be added to the phenomena of flood and typhoon events, adversely impacting the socioeconomic wellbeing and ecosystem functioning in Thua Thien Hue Province.

In general, the results show that the very high rainfall patterns which are concentrated during certain wet months would increase the already high flood risk of the study area, with associated adverse consequences, unless comprehensive and systematic adaptation measures are implemented. Conversely, the dry season is projected to be longer and more severe, which would increase the risk of drought. The longer, more severe lack of rainfall during this period may adversely impact the energy generation capacity of a number of hydropower plants (currently under construction or soon to be built) on the Huong and other rivers of Thua Thien Hue Province. The decreased dry season rainfall may also threaten the municipal water supply of Hue City and agricultural irrigation requirements and cause fresh water shortages for downstream users and ecological systems. The salinization of surface water, groundwater and soil in the coastal areas

will be likely to have negative impacts on agriculture, aquaculture and eco-tourism, as well as the unique wetland ecosystems of the Tam Giang-Cau Hai lagoons.

Table 3: Projected decadal change in annual and seasonal rainfall (%) in Thua Thien Hue in the 2010 to 2100 period, compared with the 1990 baseline, for two emission scenarios.

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

It is evident that both the flood and the drought risks and impacts from projected future climate change are very high for Thua Thien Hue Province.

The sea level rise scenarios of Thua Thien Hue have been estimated by taking average values from Hon Dau Station, representing the coastal zone of north Vietnam; and Vung Tau Station, representing the coastal zone in the south of Vietnam.

The projected sea level rise in Thua Thien Hue would reach approximately 50 to 60cm by 2100, much less than in the northern and southern parts of Vietnam and equally, less than the global projected average. However, uncertainties remain with this relatively modest prognosis, which could be skewed by a number of factors, such as geo-morphological change in the level of the sea floor. Another obstacle to accurate estimation is the discrepancy between the data measurement standards of two periods at the central marine hydromet-stations: before and after the re-unification of South and North Vietnam. Further studies need to be done to obtain more accurate projections of sea level rise in the area.

3.2. Impacts of climate change on the water resources of the Huong River Basin

For the assessment of the potential climate change impacts on water resources, different modeling methods were used, including MIKE11 and MIKEBASIN. The input data that was used included meteorological data (daily maximum and minimum air temperatures, precipitation from 1961 to 2004) and their projections for 2010 to 2100 according to various scenarios. Potential evapo-transpiration (ETo) data was calculated for the baseline year 1990 and for the periods 2020 to 2049 and 2071 to 2100 at A Luoi and Hue stations using the Thornthwaite's formula. Table 4 shows the computational results of monthly average ETo over the selected periods.

Table 4: Monthly potential evapo-transpiration (ETo) of sub-basins in 2100 (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
Total	740.6	867.5	1037.2	887.0	794.0

3.2.1 Climate change impacts on river runoff

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

Figure 7 shows the observed and projected monthly flow at Co Bi gauging station for the periods 1977 to 2006, 2020 to 2049 and 2071 to 2100 under the B2 emission scenario. The trend line shows a very small increase in the river flow. Figure 6 further shows the changes in average annual runoff for four different gauging stations for the same periods. As can be seen from this figure, increases in average annual runoff are projected for all stations. For example, the computational results under scenario B2 at Co Bi gauging station are shown in figure 7. For each of the sub-basins, the change in average annual runoff was also calculated (figure 8).

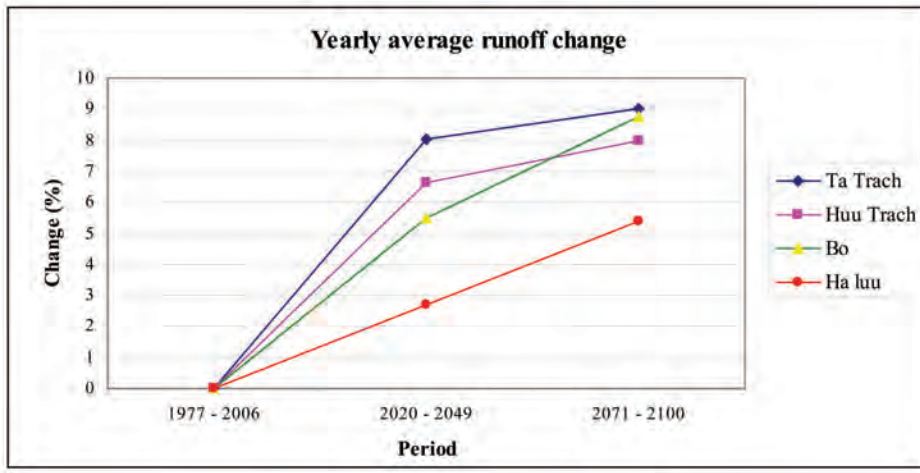

Figure 6: The average change in yearly runoff under scenario B2

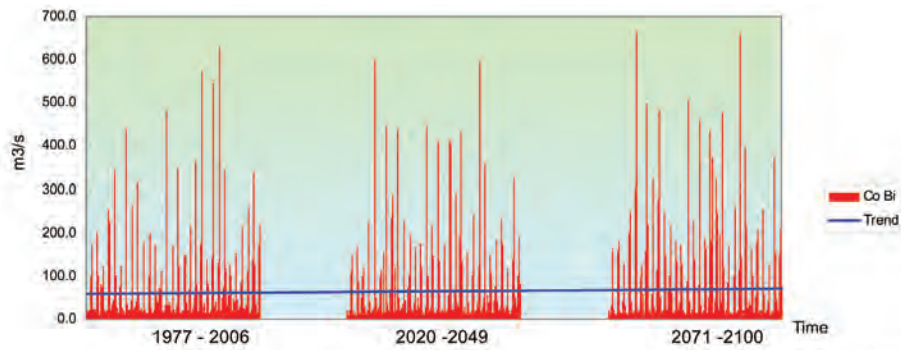

Figure 7: Change in stream flow at Co Bi station in the Huong River Basin under scenario B2

3.2.2 Flood mapping

Based on the MIKE 11 outputs, MIKE 11 GIS was used to interpolate the water levels at all cross-sections in order to construct a grid-based (TIN-based) water surface. The water surface was then automatically compared with a Digital Elevation Model (DEM) to produce and calculate flood depth maps. The flood depth maps were produced for the different emission scenarios and for different areas in the province. Some of the outputs and results from the analysis are presented below.

Table 5 shows the projected change of flood depth and flood(ed) areas in Thua Thien Hue province for the A1F1 emission scenario and compares it to the 1999 flood.

Table 5: 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
Area flooded (km²)	388.4	404.5	419.2	439.5	448.8	453.7
Flood(ed) proportion (%)	7.69	8.01	8.29	8.68	8.88	8.98

In 1999, with an average depth of 5.81m, the flooded area was 388.4km^2 accounting for 7.69% of the territory of Thua Thien Hue. By the year 2030, with the depth of flooding at no more than 6m, the flooded area would already be over 400km^2. By 2050, with the depth of flooding at 6.08m, the inundated area would be 419.2km^2. In the following decades, the depth of flooding continues to increase until by the year 2100 it is at 6.44m and the associated area of inundation would be up to 453.7km^2, accounting for 8.98% of the natural area.

Figure 8 below shows two graphs depicting the changes in flooded areas according to the B2 and A1F1 emission scenarios. As can be seen from the diagrams, both emission scenarios will result in an increase of the inundated areas in Phu Vang district. Figure 9 shows an inundation map scenario for 2100.

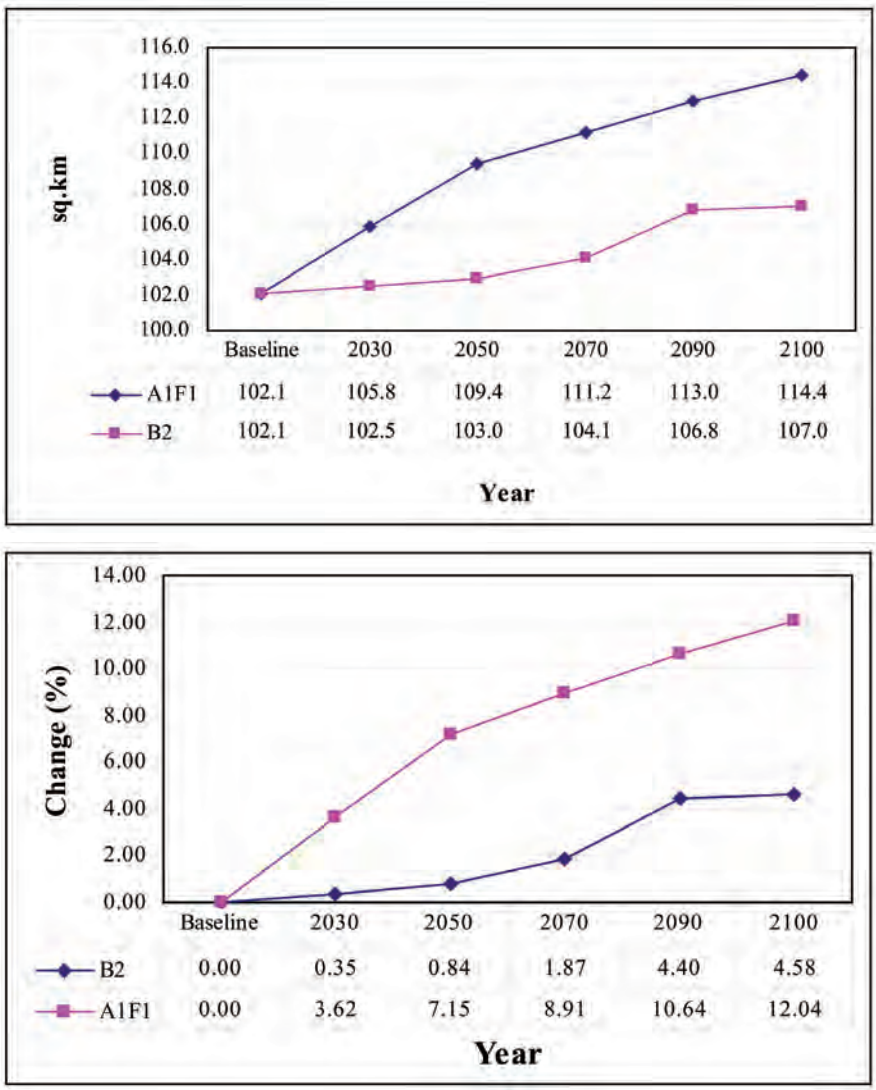

Figure 8: Change in the exttent of inundation in Phu Vang district in years corresponding with different scenarios.

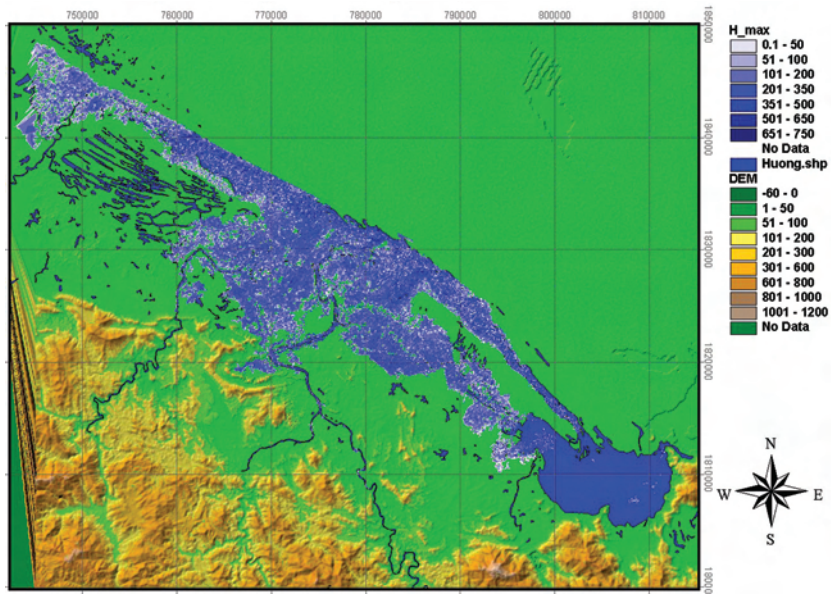

Figure 9: Inundation Map Corresponding with the Year 2100

3.2.3 Impact of climate change on salinity intrusion

The HD and AD modules of MIKE 11 have been used to estimate the salt profile, after proper calibration and verification. Scenarios for salinity intrusion simulation were developed based on the projected change in sea level as described above. The year 2002 was selected as the baseline reference because the observed data from this year was the most complete of that available. Results of salinity intrusion computation for selected scenarios are shown for some cross-sections in the main rivers. The computational results show that there will be an increase in salt concentration as time passes in correlation with sea level rise. Table 6 shows the computation results of the increase in salt concentration in one location along the Huong River.

Table 6: Salt concentration change at Pho Nam and Phu Cam (scenario A1F1)

Cross-section	Parameter	2002	2030	2050	2070	2090	2100
Phu Cam	Average salt concentration (%)	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 (%)	0.00	8.16	15.92	24.49	32.24	38.37

The results of salinity intrusion as calculated by the model clearly show that due to the effect of sea level rise and water shortage, increase in use during the dry seasons, the salinity of most rivers in the Huong River system will increase considerably. Therefore, further anti-saline measures will be required, notwithstanding existing infrastructure developments.

3.3 Climate change impacts on other sectors in Thua Thien Hue Province and local impacts at the district and commune level

Apart from assessing the impacts of climate change on water resources, the project has also looked into the impacts of climate change on other sectors in Thua Thien Hue Province and Phu Vang district. In addition, more detailed assessments have been carried out in order to better understand the potential impacts of climate change on two specific areas in the province: Phu Vang District and Chan May–Lang Co Special Economic Industrial Zones.

The impact assessments were largely based on interviews and workshops/ meetings with local and external stakeholders at provincial, district and commune levels, using UNEP and IPCC methodology, as well as participatory approaches. The assessment was done for all relevant sectors, natural and water resources (as above), biodiversity, agriculture, aquaculture, forestry, industry and energy, transport and construction, culture and sport, tourism, trade and services, with an emphasis on the highly important coastal zone of Thua Thien Hue Province.

Analyses of data and information on the impacts of and vulnerability to climate change for the poor people in Phu Vang district and in one particularly vulnerable commune –Thuan An – were also conducted. The information and data was obtained through a variety of participatory methods including stakeholder analysis, participatory rural appraisal, semi-structured interviews, focus group discussions, etc. A brief summary including some representative examples of the climate change impacts is presented here. The full details are available in separate technical reports.

3.3.1 Climate change impacts on agriculture

- Most of the current rice paddies could be flooded during wet season and salinity intrusion could take place during the dry season, especially in areas of low elevation and land near the river/ lagoon, leading to a decrease in food yield and a threat to food security.
- Some riparian protective forests could become flooded and saline intrusion could lead to the disappearance of some rare and valuable genetic resources.
- Rice plants, short-term and long-term planted trees and long-term, newly developed industrial trees such as rubber, may suffer more damage when the frequency of natural disasters increases. The crop pattern, seasons and even productivity could also expect to be affected by climate change.
- An increase in animal, livestock and crop diseases and infections through the spread and introduction of new pests and pathogens and crop diseases may take place. More pesticides and chemicals might be used to combat this, increasing the danger and risk of pollution.
- An increase of erosion and soil degradation, leading to lower crop productivity may occur.

3.3.2 Impacts on natural fisheries and aquaculture

- Disruption of the fisheries due to changes in the seasons for aquatic farming and shortening the lifetime of certain farming tools.
- Changes in the currents at some river mouths, affecting the itinerary of fishing boats and other ships and fish migration/spawning routes.
- Changes in the natural environment, leading to changes of biodiversity, the behavior of aquatic animals and changes of genetic diversity of aquatic species.
- When temperatures exceed 40ºC, the growth of animals in aquaculture ponds is slowed, and they may even die, affecting farm productivity. In addition, bacteria and fungi multiply more profusely, resulting in epidemics and eutrophification of farming ponds in the lagoon.
- Infrastructure (e.g. electricity, roads, levees and canals inside the fields) serving the aquaculture and fishery sectors will degrade more quickly.

3.3.3 Impacts on biodiversity

Climate change and sea level rise may increase the salinity of the brackish lagoon water, adversely affecting the ecosystems of the Tam Giang-Cau Hai wetland and current conservation efforts aimed at protecting areas such as the unique bird habitat of O Lau and the mangrove forest in Ru Cha. Many endangered species would be placed at high risk of extinction. The projected extension of the lagoon and frequently flooded area would alter the shoreline and estuary and destroy the large mangrove forest and habitat of many species, including those that are endangered.

The solutions proposed and implemented (weir, dam, etc.) to address salinization due to sea level rise could affect migratory animals and micro organisms, including the migration for reproduction of "native" species such as the flower eel, ebony eel and spotted sardine. This could also restrict the transition and interaction between the freshwater, brackish-water and marine ecosystems, potentially limiting the adaptation capacity of wildlife, domestic animals and crops.

A rise in sea temperature could also affect coastal and marine ecosystems such as coral reefs.

3.3.4 Impacts on the coastal zone

The coastal zone accounts for 30% of the area and more than 30% of the human population of Thua Thien Hue Province.

Climate change impacts on the coastal zone in the province include:

- The enlarging of wetland and flooded areas in Tam Giang-Cau Hai lagoon will decrease the land of the delta and coastal plain, increasing the downstream effects of floods on the Huong River.
- The flooding of terrestrial ecosystems may result in the loss of mangrove forest.
- Eroded seashore, decreased land for cultivation and dwindling residential areas will adversely affect local incomes and livelihoods, including those of fishermen, farmers, industrial workers and enterprises around the lagoon and downstream of the Huong River.
- Threats to infrastructure and transportation networks (especially sea dyke and coastal highways), irrigation and waterworks which were designed and constructed without consideration of sea level rise; will indirectly increase public and private sector expenditure on construction and protection of infrastructure in lowland areas and seaports.
- Increased pollution of the aquatic environment in the coastal zone and saline intrusion in the Huong River, would lead to (fresh)water scarcity.
- There could be an indirect contribution to increased unsustainable exploitation of natural resources, and associated disputes and conflicts regarding natural resource use in the basin.

3.3.5 Impacts on tourism

Tourism is prominent in Thua Thien Hue Province due to its natural and cultural features. However, climate change may harm the economic benefits resulting from the culture, sport, tourism, trade and service sectors.

Sea level rise may inundate coastal beaches of the province, some of which could disappear, while others will move inland reducing access to the seaside. Sea level rise may also damage the cultural and historical heritage, protected areas and related infrastructure of the ancient city of Hue and the province.

3.3.6 Impacts on the Chan May–Lang Co Special Economic Industrial Zones

Located along the southern part of the Thua Thien Hue coastline, the Chan May–Lang Co Special Economic Industrial Zones (SEIZs) serve as the centre of the province's economy and tourism sector. However, the SEIZs have recently been faced with increased storms and floods events and sea level rise.

Table 7: Potential severity of disasters and related impacts in Chan May–Lang Co SEIZs

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

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

According to the socioeconomic development plan and vision, by the year 2020 the SEIZs will be the international trading and transport hub of central Vietnam. Chan May–Lang Co will have a special duty-free trade area of 962ha and an industrial park of 560ha, while Chan May Port will be developed with a total land and water area of 684ha. Chan May Town will consist of 1650ha and in the tourist area near Lang Co-Canh Duong-Lap An lagoon will encompass 3700ha.

In recent years, the Chan May–Lang Co area has felt the effects of many natural disasters such as floods, flash floods, whirlwinds, landslides, and river bank and coastal erosion. In particular several strong typhoons occurred, with a wind scale of 9 to12 and storm surges of up to 1.5m in typhoon No. 6 in 2006 and 1.7m in typhoon CECIL in 1985 which caused substantial damage.

If potential climate change impacts are not adequately considered as early as possible, much of the above mentioned undertakings planned for the SEIZs will be at increasing risk, which may negatively impact economic productivity.

During this project, interviews and surveys were conducted and a number of meetings with a "CCP expert group" were carried out as part of efforts to integrate climate change adaptation into the planning process and construction of the SEIZs, and to raise the awareness of private and public sector actors in the area.

The SEIZs' management board has acknowledged the potential challenges that climate change and the associated increase in disasters may bring, and this was facilitated by the preparation of the vulnerability and disaster risk maps produced by the CCP group.

Expert assessment of the impacts of disasters on different zones and sectors in Chan May–Lang Co area reveal that the main events likely to arise are typhoons, sea level rise, floods, droughts and salinity intrusion. The agriculture, aquaculture forestry, irrigation, water resources and water supply sectors are those likely to bear the brunt of any increase in disasters. Table 7 highlights the potential severity of these impacts.

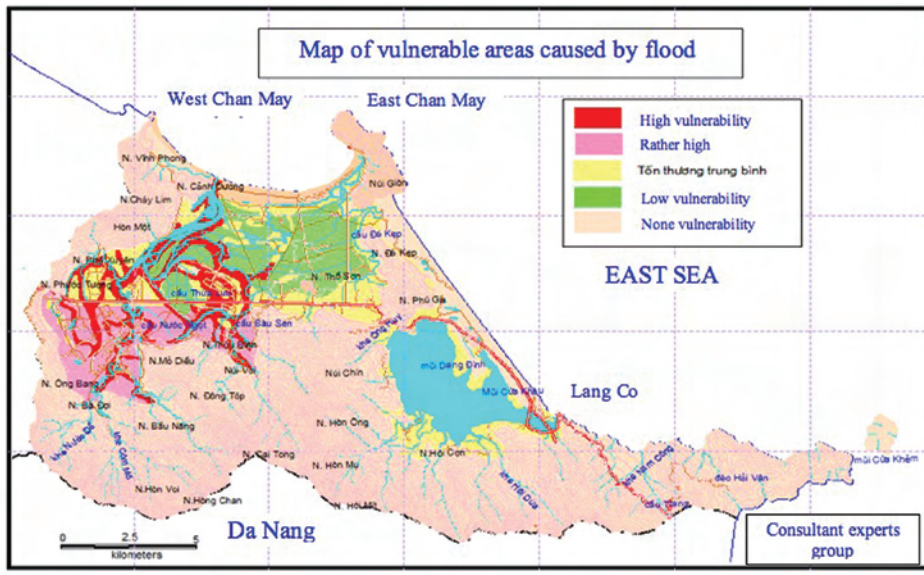

Figure 10: Flood vulnerability map for Chan May–Lang Co SEIZs

3.3.7 Climate change and disasters in Phu Vang district and Thuan An commune

With agriculture, fisheries and aquaculture being the mainstay of the local economy, Phu Vang district faces serious challenges from disaster events and the potential effects of climate change. Results from the stakeholder consultation process as well as the results from the participatory rural appraisal and other surveys indicate that the types of disasters and climate change impacts witnessed in the district are similar to those of other coastal and lagoon areas of Thua Thien Hue Province. However, a number of findings specific to Phu Vang district were exposed.

The most threatening disasters as perceived by local people are floods and storm events, which could trigger a sudden and strong change of the sand bars and lagoon basement, the so-called "lagoon gate opening" effect. Such an event did occur in Hoa Duan commune in 1999, where 64 households were washed out to sea and hundreds of people died or went missing.

Coastal hydrodynamic change can lead to the destruction of important infrastructure like dykes as well as houses. Very deep erosion (up to hundreds of meters) may be seen in one place and

heavy sedimentation in another. Engineered structures, such as the H-form concrete bars built by the French during colonial times at 30m from the shoreline, could help prevent some erosion. Additional studies should be done to better understand this hydrodynamic process and identify proper solutions.

Indigenous knowledge has proved very useful to local communities in predicting and coping with disasters but in recent years it has become less effective as weather and climatic patterns shift.

The flooded area is likely to become more extensive due to climate change, with the effects of a November 1999 catastrophic event (when 36.4% of the area flooded) potentially reaching up to 40.4% if a similar event were to occur in the future (see table 8).

Calculations of projected flooding in Phu Vang district are as follows:

Table 8: Projected area and proportion of land flooded in Phu Vang District according to scenario A1F1

	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 flooded area (%)	36.4	37.2	39.0	39.2	40.3	40.8

Drought and salinity intrusion are also expected to increase in Phu Vang based on the climate change scenarios. By the end of the century, salinity in the Huong River mouth could increase by 20 to 40%, and saline intrusion may penetrate 2 to 3km further upstream than at present, if proper counter measures are not undertaken.

Thuan An town in Phu Vang district is located on the depressed estuary plain of the Huong River Basin. Part of the lagoon area houses of Thuan An's villages, while another seven are near Tam Giang-Cau Hai lagoon and five are close to the sea (figure 11).

Figure 11: Map of Thuan An Commune

A number of interviews, group discussions and workshops were carried out in Thuan An to help identify the real-life local context of disasters and climate change impacts, the socioeconomic and environmental situation, autonomous adaptive capacity and relevant indigenous knowledge and

local customs. This has resulted in a number of area specific outputs, including a detailed vulnerability map (see figure 12) and some village specific adaptation measures. Apart from collecting information about vulnerable areas, the group discussions have also greatly increased the awareness of local people about the potential threats of climate change.

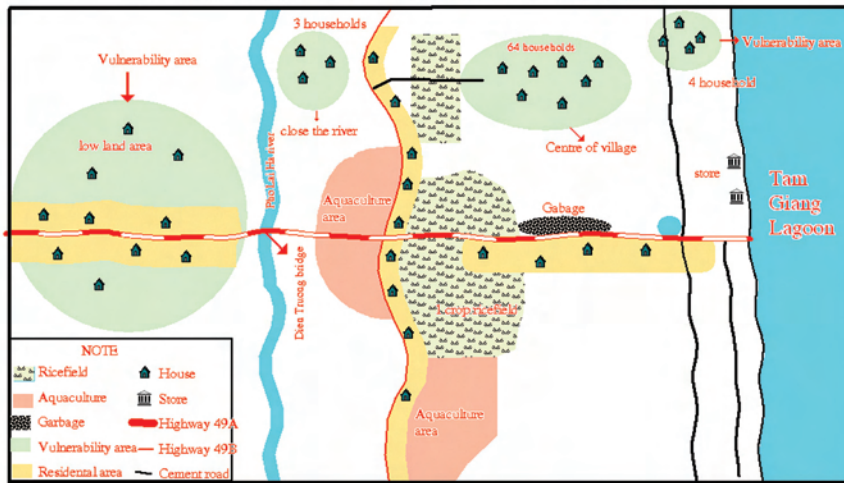

Figure 12: Dien Truong Village's Vulnerability Map, Thuan An Town

4. Working towards an adaptation policy for Thua Thien Hue province

The Integrated Coastal Zone Management (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.

The ICZM strategy document was promulgated at the national level in 2003. The strategy of the ICZM agrees with the strategy of adaptation to climate change in the approach, methods of implementation and objectives of environment protection for sustainable development. As such, the document could serve as an appropriate basis for implementing climate change policies and measures at the provincial level.

At this moment, however, the process of preparing the ICZM strategy has not yet considered the changes in climate as well as their impacts on natural conditions of the study area. Therefore, the NCAP project, in close consultation with relevant provincial stakeholders, took the initiative to integrate some climate change adaptation proposals into important sections of the ICZM strategy. The following proposals have been made for inclusion into the ICZM Strategy:

- Raising management capacity for the ICZM strategy in areas likely to be most affected by climate change. Raising awareness and knowledge among community members, local government authorities and policy makers on future climate-related disasters and adaptive measures for the ICZM to respond to climate change.
- Re-development of the coastal zone management framework protocol and action plan in the administrative system of Thua Thien Hue focused towards sustainable development, shared benefits and adaptation to climate change.
- Re-recognition of the areas, fields and communities most vulnerable to climate change impacts and identification of effective measures to maintain sustainable development in these specific zones.

- Re-assessment of the carrying capacity of the coastal zone and lagoons and potential adaptive capacity of relevant sectors (agriculture, aquaculture, tourism and industrial development) in the coastal zone.

5. Lessons learned and strategic recommendations

5.1 Lessons learned

In recent decades Thua Thien Hue Province has experienced an increase in climate change-related events: significant increases in temperature, wet season rainfall, flooding and inundation have been noted. Consequently, incidences of drought, river bank and coastal erosion, and salinity intrusion have become more severe. Thanks to project activities supported by the NCAP, policy makers and communities in Thua Thien Hue have become more aware of the extent that climate change will have on all sectors of society and in particular on agricultural production and in coastal areas. In the course of the project, the following lessons have been learned.

5.1.1 Take advantage of local resources and existing knowledge

Optimal and creative use of all available local resources and consideration of all relevant past and ongoing studies and projects was a priority focus of this project. Within the extended project time-frame, IMHEN as the implementing party was able to produce a variety of outputs on a limited budget: a climate change impact assessment for water resources at river basin scale; downscaled climate change scenarios for a limited area; climate projections and hydrological modeling; participatory studies; local adaptive capacity assessments; and adaptation measure analysis at the provincial, district and town levels. All of the initial targets were reached to varying extents.

The above results were achieved in part thanks to the proper mobilization of local resources, including information and data, technical, financial and human capacity and collaboration with other projects, assessments and activities and the sharing of the results of such. This last point will be described further below.

5.1.2 Cooperate to reduce costs and avoid duplication of effort

Close collaboration with relevant development projects working in the same area or sector, or with similar objectives, should be encouraged to avoid the duplication of effort and to maximize the sharing of information, technical advice, reports, networks of contacts, and financial and human resources.

In the first phase of this project, two meetings were organized with representatives of different organizations and initiatives in Thua Thien Hue Province and especially in Phu Vang district (including IMOLA, ICZM, FAO, CECI, PVC, Kyoto University, and ABD) where the participants shared information and experiences, contacts and networks. All the participants acknowledged the importance of such a dialogue and mechanism for collaboration. However, it was also recognized that most of the projects still have weak links with one another and have no budget allocations to support coordination. Moreover, there are many constraints limiting effective collaboration, such as the lack of a dedicated platform for cooperation and communication and the bureaucracy of some local institutions, among others.

In this regard, the establishment of a special unit for coordination of relevant activities with small but secure budget allocation, possibly independent from the local government, would be highly beneficial. At present, such an inter-agency coordination body does not exist, so it is recommended to encourage all donors and investors to allocate a certain amount of project budgets to a “collaborative fund” for this important and potentially very cost effective mechanism.

5.1.3 Use a combination of top-down and bottom-up participatory approaches

Local communities and the rural poor are often the most vulnerable sectors of society who will feel earliest and bear the full brunt of the negative impacts of climate change. As these groups are also

among the intended project beneficiaries, they need to be involved in the process of adaptation at all stages, from initial project development to the monitoring and evaluation of the project outputs. Therefore, a bottom-up approach is essential in designing practical adaptive measures to match the specifics of the local context and in developing small-scale adaptation and other projects.

The bottom-up approach may not be entirely sufficient, however, for a more strategic project aimed at influencing policy-making and implementation. If this is the case, a combined approach would be the most effective.

5.1.4 Translate scientific study results into a language understandable by the end-users

One of the most difficult but important tasks in a project such as this is to reformulate scientific conclusions into a language and format that is easily understood by the different target groups: provincial leaders and policy makers, private and public sector managers, local authorities and local communities, and poor people.

Rural inhabitants and the urban poor may not speak the same language as technical experts and scientists, and often have little free time or interest in complicated scientific issues, so all project and study results should be simplified and presented in a locally coherent way.

Conversely, policy makers and national authorities require concrete and reliable evidence – figures, data and facts that should be related to or spark their interest (political, economic or other), with an emphasis on shorter term decisions and plans as abstract ideas or long term challenges do not always catch these stakeholders' attention.

The potential impacts of climate change over the long term are often ignored or misunderstood by local communities and state authorities. Some of these actors may also be already (intentionally or not) undertaking what could be considered as autonomous adaptation measures. The task of the experts and project teams is to raise awareness and understanding, which may lead to concrete positive actions.

5.1.5 Use indigenous knowledge and expert opinion wisely

Local people know much better than others their needs and fears, the location of areas most vulnerable to climate change and disasters and economic or livelihood opportunities in and around their communities, but they can often benefit from the technical support and objective view provided by outside experts.

Confusion regarding the concept of climate change, related information and relevant countermeasures – for example the difference between mitigation and adaptation – can be common place, so some clarification and capacity building is usually needed.

During project implementation, many new ideas and findings may arise while working with local people or governmental bodies. It is often the case that project experts have not considered all aspects of a project, especially if prior consultations were not undertaken with local communities. So while managers may have a good idea of the overall project objectives, creative and innovative solutions may be provided by project stakeholders, ideas which could even change the implementation direction or intended outputs. In such a case, the purpose and overall objectives of the project can remain but a reorientation of certain specific objectives or outputs may be useful to better fit the practical reality.

5.1.6 Think globally, act locally

Regional, national and local adaptation to climate change should be linked to the global context in terms of knowledge and information availability, technology transfer and financial support from, and experience sharing with, the international community. Such cooperation can bring benefits and opportunities to local people, as is the case with the NCAP project for Thua Thien Hue Province, Vietnam.

However, adaptation to climate change needs to also begin with, and focus on, the everyday actions of individuals to encourage changes in awareness, attitudes and behavior. In order to help achieve this, near-term concrete targets to adapt to climate variability and disasters should be promoted and local development challenges may need to be addressed.

5.2 Strategic recommendations

Despite the emphasis given to achieving accelerated economic growth, the Government of Vietnam acknowledges that controlling and reducing the consequences of climate change and disasters are also key priorities. State and industry responses to climate change would have to be carried out systematically and be consistent with the policies and plans of various sectors and regions, in particular with the national economic development plan as well as that of a province such as Thua Thien Hue.

The results of this project should be used in mainstreaming climate change adaptation into the provincial socioeconomic development plan, as well as into the Thua Thien Hue ICZM action plan, which should be revised in 2009. A number of initial difficulties were encountered by the project team while trying to propose the integration of climate change adaptation considerations into policy-making mechanisms and administrative processes. Fortunately, with the increasing awareness of the Government of Vietnam regarding potential climate change impacts and risks and the ongoing 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 be implemented at the provincial level very soon.

5.3 Specific recommendations for Thua Thien Hue Province

The following are specific recommendations for the most vulnerable sectors and areas – agriculture, water resources and coastal zones – of Thua Thien Hue Province:

5.3.1 Adaptation options for agriculture and rural development

Promote appropriate changes in crop patterns and domestic livestock in high risk zones, convert low-productivity rice areas into aquaculture; assess and familiarize with new crop seasons, implement suitable technical practices for agriculture.

Use hardy crop varieties that can overcome excess water, drought and extreme weather conditions. Reorientate the existing 5 million ha forestation program towards an upstream protected forest, the coastal green belt and mangrove forests.

5.3.2 Adaptation options for water resource management and disaster prevention

- Develop and implement an integrated water resource management plan for the province considering climate change impacts and increasing water demand.
- Improve the water regulation and flood protection systems, dykes, irrigation infrastructure, dams and reservoirs in order to protect and better exploit cultivated areas.
- Develop and improve the disaster management and search and rescue plan for vulnerable locations.

5.3.4 Adaptation options for coastal and lagoon areas

An adaptation framework should be established for the coastal zone and lagoon area which should have the purpose of: preventing loss of life and property, avoiding development in disaster-prone areas and ensuring that critical coastal ecosystems, such as wetlands and coral reefs, are protected and remain functional. Specific adaptation options could include:

- Good practical implementation of the ICZM strategy with consideration of climate change and its potential impacts on the sustainable development of the coastal zone.
- Protection for populated areas: construction of sea dykes is the measure of choice to prevent erosion in densely populated coastal areas. However, sea dykes do not resolve the underlying cause of erosion, and they can promote the offshore movement of beach sediments. The dykes 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 development, the use of setbacks and relocation could be considered.
- 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 land areas, 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 could be useful. Sea dykes, however, should be used only in key locations, such as along the edges of important waterways, as they tend to cause downstream erosion and require continual 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: in areas with little infrastructure, the costs of protection are likely to be prohibitive, and relocation or modification of structures to accommodate surface flooding should be considered. In more populated areas, strategies to allow over-wash sediment to naturally increase the elevation of the coastal zone 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 the Thua Thien Hue authorities, as nearly all inhabitable land is under some form of customary ownership.