

## WATER AND CLIMATE CHANGE IN THE LOWER MEKONG BASIN:

Diagnosis & recommendations for adaptation

Water and Development Research Group, TTK &  
Southeast Asia START Regional Center



# **Water and Climate Change in the Lower Mekong Basin: Diagnosis & recommendations for adaptation**

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## PREFACE

This Final Report presents the main findings from the research carried out within the research project “Water and Climate Change in the Lower Mekong Basin”. The project was implemented between May 2008 and April 2009, and it was funded by the Ministry for Foreign Affairs of Finland. For more information about the research project, including its publications, please have a look at the project web site: <http://users.tkk.fi/u/mkummu/water&cc>

The research was carried out jointly by Water & Development Research Group at the Helsinki University of Technology, Finland and Southeast Asia START Regional Center at the Chulalongkorn University, Thailand. Water & Development Research Group is an interdisciplinary research group operating at the Helsinki University of Technology (TKK). The Research Unit has a long research tradition in water and development issues as well as in integrated management of water resources. The group has been working in the Mekong Region for several years, and it has been e.g. part of the WUP-FIN Project under the Mekong River Commission. More information: <http://www.water.tkk.fi/global>

Southeast Asia START Regional Center at the Chulalongkorn University is the regional research node for the Global Change SysTem for Analysis, Research and Training (START) network that supports multidisciplinary research on the interactions between humans and the environment. The center has been working in the Mekong region extensively in an integrated way, making use of both natural science and social science approaches, with focus on research and capacity building. The center is well linked to the actors working on climate change-related issues in the region, and during the past years it has been involved e.g. in the Global International Waters Assessment (GIWA) and number of studies on climate change and adaptation in the Mekong River Basin. More information: <http://www.start.or.th>

This research would not have been possible without close cooperation with people from different institutions in the region: thank you for your support and cooperation! We also benefited greatly from the discussion in the two workshops that we organised in Phnom Penh and Can Tho: thank you for the participants of those workshops for your active engagement! Thank you very much to our informants in the field study villages of the Tonle Sap as well as to our Cambodian colleagues, Mr Yim Sambo and Mrs Lun Sereimorokot, for your important contribution in the field research.

In Cambodia, the staff at Cambodian Climate Change Office, Royal University of Phnom Penh and Tonle Sap Basin Authority have been particularly important in supporting our research. In addition, people from several other organisations –including CENTDOR, CEDAC, FACT, UNDP, ITC and Tonle Sap Biosphere Reserve Secretariat– provided support and constructive comments. In Vietnam, cooperation with the DRAGON Institute at Can Tho University as well as Nong Lam University, AIT-HCMC, Knowledge Development International Center, WWF-Vietnam and IUCN-Vietnam was particularly important and also made our workshop in Can Tho such a success. At more regional level, we have benefited from cooperation and constructive comments provided by the people from the WWF-Greater Mekong, the Mekong River Commission, M-POWER network, CSIRO, The Met Office Hadley Centre, Asia-Pacific Network for Global Change Research, MacArthur Foundation and the Finnish Ministry for Foreign Affairs. A special thanks goes to our colleagues at Finnish Environment Institute and YVA Ltd. for supporting our work particularly on hydrological modelling.

This report aims to contribute to the discussion about the climate change-related impacts and adaptation strategies in the Lower Mekong Basin. We welcome any comments and feedback on our research: please send them by email to [olli.varis@tkk.fi](mailto:olli.varis@tkk.fi)

On behalf of the research team,

*Olli Varis*  
Team Leader  
Professor, TKK

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# EXECUTIVE SUMMARY

## INTRODUCTION

Current climate change estimates indicate that major environmental changes are likely to occur due to climate change in practically every part of the world, with majority of these changes being felt through modification of hydrological cycle as e.g. floods, droughts and storms. Climate change impacts are also estimated to be particularly severe in many developing countries of the world.

It is therefore no surprise that climate change adaptation has become one of the focal points of current development discussion. The negative impacts of climate change are likely to bring new challenges as well as to magnify already existing ones, particularly when looking things at more long term. The changing climate may also bring opportunities, many of which are not yet fully understood. Consequently, climate change adaptation is an important issue to focus on, and -due to close linkages between climate and hydrological cycle- it requires particularly thorough understanding of water and related resources.

This executive summary presents the key findings from a research project that looked at the interconnections between water and climate change in the lower basin of the Mekong River in Southeast Asia<sup>1</sup>. Due to its relatively short duration (11 months) and limited resources (104'368 euros, 28 man-months), the project was not able to cover the entire Mekong River Basin or all aspects of climate and water resources, but focused its efforts on the hydrological impacts of climate change as well as related adaptation strategies in the Tonle Sap area of Cambodia and the Mekong Delta of Vietnam. The project can thus be seen as a kind of scoping study that aimed to analyse some of the main issues related to climate change adaptation in these two areas as well as to recognise possibilities for future research and action.

The research project, and therefore also this Final Report, focused on four thematic components:

- 1) Climate change scenarios
- 2) Hydrological impacts
- 3) Livelihoods & local adaptation strategies
- 4) Adaptation policies

## CLIMATE CHANGE SCENARIOS: WARMER & WETTER

High resolution future climate projection data was simulated for the 21<sup>st</sup> Century by PRECIS regional climate model that used as input dataset from ECHAM4 Global Circulation Model under two different climate scenarios (A2 and B2), and downscaled it for the Mekong Region.

The results from the climate change scenarios indicate that the Mekong Region will in the future become slightly warmer, but the duration of warm periods will extend much longer and cover much wider areas than currently. The rainfall estimates show fluctuation in the first half of this century, but then increasing trend during the latter half of the century. This increasing trend results from increasing rainfall intensity, as the length of the rainy season is estimated to be more or less the same than currently.

## HYDROLOGICAL IMPACTS: CHANGES IN FLOODING

The hydrological impacts of climate change were simulated for the period 2010-2049 based on two main impacts: 1) changed basin hydrology due to climate change-induced changes in temperature

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<sup>1</sup> For more information on the project and its publications, visit the project's web site at: <http://users.tkk.fi/u/mkummu/water&cc>



and rainfall, and 2) sea level rise. Subsequently, the modelled climate data was used as input for basin-wide hydrological model (to simulate future river run-off) as well as for ocean circulation model (to simulate sea level change at the mouth of Mekong River). The impacts of these two climate-related phenomena on the hydrology in the Cambodian floodplains and the Tonle Sap as well as in the Mekong Delta of Vietnam were modelled both separately and together.

The modelling results indicate that in the case of the Tonle Sap, the impacts of changing climate are largely to be felt through changes in the flows of the Mekong River, altering the area's unique flood pulse system and therefore also the high aquatic productivity of the lake-floodplain system. In the Mekong Delta of Vietnam, the impacts are going to be partly felt through changes in the basin, but also through increase in sea water level. Overall, the impacts caused by sea level rise are very consistent throughout the simulated period of 40 years, increasing in magnitude decade by decade, whereas the impacts of changed basin hydrology are more varied in both magnitude and direction of change.

A majority of the simulated climate scenarios produced similar results in terms of hydrological impacts: the future flood pulse in the Tonle Sap and the Cambodian floodplains is likely to be wetter with higher water levels and more extensive flooded area as well as longer flood duration. Notable is that also the average water level during the dry season (February–July) is likely to increase. In the Delta the estimated changes are more diverse, and include e.g. possible extension of flooded area as well as changes in flood arrival dates.

### **LIVELIHOODS & LOCAL ADAPTATION STRATEGIES: INCREASING VULNERABILITY**

The third research component looked at the livelihoods and their resilience as well as local adaptation capacity to environmental and water-related changes in both the Mekong Delta and the Tonle Sap. The results from the field studies carried out in the Tonle Sap area point out that

while people are well adapted to remarkable seasonal variation of the Tonle Sap's waters, their adaptation capacity towards unusual water regimes –such as extraordinary high floods or sudden storms– is relatively limited. Particularly limited seems to be the adaptation capacity of the poorest groups, as their already low living standards and asset-base intensifies their vulnerability to additional challenges. The study results also indicate that one of the most efficient strategies for enhanced adaptation is to increase the general standard of living and the prerequisites to maintain a productive livelihood. Equally important is to support local capacities and institutions to cope with both sudden shocks as well as with more long-term stresses and changes.

In addition, the results from the field studies in the Tonle Sap as well as from the stakeholder consultation in the Mekong Delta indicate that any efforts to enhance local adaptation capacity should build on existing livelihoods and strengths at the local level as well as lessons learnt from the unexceptional events of the past. The informants both in the Tonle Sap and the Delta had several ideas about the sort of activities through which they could improve their future livelihoods, and thus to enhance their resilience and adaptation capacity. Supporting and nurturing these ideas can thus be seen as one of the keys for enhancing the adaptation capacities at the local level.

### **ADAPTATION POLICIES: REMEMBERING THE BROADER CONTEXT**

The analysis of climate change adaptation policies show that both Cambodia and Vietnam are actively engaged in developing their strategies and policies to respond to climate change impacts. In addition, the situation is improving at the regional level though e.g. the climate change adaptation initiative of the Mekong River Commission.

When looking at the current adaptation strategies, it becomes clear that they are largely built on sectoral approaches and many of them suffer from the lack of coordination and cooperation between different actors. Also the understanding of the broader context related to climate change adaptation seems to be limited, and most of the current adaptation

strategies don't properly consider: 1) other 'change factors' impacting water cycle (such as large-scale hydropower development), and 2) social, economic, institutional and political issues related to climate change adaptation. Consequently, extending current adaptation strategies to consider also these broader issues is critical for the strategies really to be able to respond to potential future impacts of changing climate and environment.

## CONCLUSIONS & RECOMMENDATIONS

The analysis of the hydrological impacts of climate change indicate that climate change is likely to bring remarkable changes to the Mekong River Basin, with most remarkable impacts being felt in the longer term i.e. towards the end of the assessment period (2010-2049). Both of our study areas, the Tonle Sap and the Mekong Delta, are particularly vulnerable to such changes.

At the same time it is important to note that climate change is not the only 'change factor' impacting the Mekong flows, but e.g. planned large-scale hydropower dams is estimated to have a remarkable impact on both the quantity and quality of the flow. When comparing the impacts of these two changes –hydropower development and climate change–, it is interesting to notice that their estimated impacts to many hydrological variables are estimated to be opposite. The clear exception to this is the dry season water level that is estimated to increase in the floodplains due to both hydropower development and climate change. Given the radical negative impacts that increased dry season water level is estimated to have to the floodplains ecosystems, this kind of combined impact is a serious concern particularly for the Tonle Sap and its high fish production and should therefore studied more carefully.

In addition, the impacts from climate change and water development are likely to occur at considerably different timescales, and they cannot therefore be considered to 'balance off' each other. While the most remarkable changes in climate-related variables such as precipitation and sea level rise are estimated to occur only in the time span of several decades, the changes caused by hydropower development e.g. in terms of reservoir capacity, are going to be felt with much shorter timescale, possibly already over next 5-15 years.

When considering the combined impacts of different 'change factors', it is therefore clear that the assessment of potential impacts of climate change must not be carried out separately, but together with other potential change factors. The impacts of these different changes should also be considered in shorter as well as in longer term. Consequently, to fully understand the combined impacts of these different changes, a cumulative impact assessment incorporating the different changes at different timescales should be carried out.

In addition, due to long time perspective required for climate change adaptation, broader socio-political contexts and their future evolution needs to be considered as well, as political, social and economic issues have at least as important role in strengthening the adaptation capacity than the understanding of physical aspects of climate change impacts itself. This also highlights the fact that climate change adaptation should be considered as a development issue, rather than just as an environmental one. For the same reason the adaptation asks for broad, multi-sectoral approach. To overcome the challenges caused by currently dominating sectoral approaches for adaptation, we propose an area-based adaptation planning approach to be applied to properly capture the local socio-political and economic contexts and conditions.



# 1 INTRODUCTION

## RESEARCH CONSORTIUM:

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 Southeast Asia START Regional Center (SEA START RC), Chulalongkorn University, Thailand

**Team leader:** Professor Olli Varis, TKK

**Active:** 05/2008-03/2009 (11 months)

**Total budget:** 104'268 EUR

**Funding:** Ministry for Foreign Affairs, Finland

The Mekong River Basin is currently undergoing rapid social, economic and political changes that have wide-reaching ecological and social consequences (Varis et al. 2008). Within past years, climate change has emerged as one potential additional driver, particularly in terms of more long-term changes.

The regional development and planning organisations – most importantly the Mekong River Commission (MRC) and the Greater Mekong Subregion (GMS) Program – have had a major role in the planning and impact assessment activities related to water and natural resources management in the basin. The environmental, social and economic impacts related to the diverse and extensive developments that are taking place in the basin are estimated to be massive, and need thorough diagnosis and itemized consideration in both national and regional development planning.

The level of knowledge on water resources, land use and livelihoods in the Mekong Basin has been improving rapidly over the past decade. However, knowledge about the linkages of these to the predicted changes occurring in the basin is still insufficient. Particularly scarce has been the information related to longer-term impacts of climate change on the dynamics of the Mekong's water resources. Those dynamics form the basis of the livelihoods of millions of people living in the basin, with people living in the lower reaches of the river in Cambodia and Vietnam being exceptionally dependent on the basin's water resources.

During just last year or so, climate change -related studies have been increasingly carried out at regional, national and local levels, and the level of knowledge on climate change impacts and climate change adaptation is therefore improving rapidly. At the same time, the on-going “boom” on climate change -related initiatives raises concerns about possible overlaps and lack of coordination between different initiatives.

The objective of the research project is to investigate the interrelations of climate variability and change and water resources in the Lower Mekong basin, and to provide recommendations regarding climate change adaptation. Climate change adaptation can be concisely defined as a process by which individuals, communities and countries seek to cope with the consequences – both positive and negative – of climate change (UNDP 2004). The process of adaptation itself is of course not new, as people have throughout the history been adapting to changing conditions, including environmental changes such as natural long-term changes in climate.

There are some key points that have guided our research and analysis. First of all it is important to note that in the two study areas –like practically in any other place in the world– it is not useful to look only at climate change and its potential impacts to the water system. Instead, climate change should be regarded as one of the many 'change factors' that are likely to cause changes on hydrology, natural resources and, consequently, on livelihoods. In a similar manner, it is important not to look at the adaptation capacity just to the impacts caused by

the climate change, but to the variety of impacts likely to occur in the areas due to combined effect of different changes. For this reason, it is crucial also to look at the environmental impacts in the study areas both in shorter and longer term.

## 2 CLIMATE CHANGE SCENARIOS

### 2.1 INTRODUCTION: PRECIS AND ECHAM4

As part of the analysis of future climate scenarios in the Mekong Region, high resolution climate projection over 21<sup>st</sup> century was developed for the region to provide climate change scenarios for further impact analysis. The regional climate scenarios were simulated at high resolution of .22 degree (approximately 25kmx25km), and rescaled to resolution of 20x20km based on dynamic downscaling process using PRECIS<sup>2</sup> regional climate model based on ECHAM4<sup>3</sup> Global Circulation Model (GCM) data.

To analyse the potential changes in climate, two climate scenarios were generated based on two different CO<sub>2</sub> rising schemes, SRES A2 and B2 (IPCC 2000). The use of two different climate scenarios, instead of just one, gives better understanding of the potential range of future climate change projections. These climate scenarios were then used as the basis for the actual climate change impact analysis in the Mekong Basin. Basin-wide hydrological analysis was carried out with distributed hydrological model that uses the climate scenarios as boundary conditions. Next, the estimated climatic changes under the two scenarios are discussed in more detail with the help of two key variables, temperature and precipitation.

### 2.2 ESTIMATED CHANGES IN TEMPERATURE AND RAINFALL

In terms of estimated changes in temperature, both of the used climate scenarios, ECHAM4 A2 and B2, indicate that the Mekong Region will in the

future become slightly warmer, with the duration of warm period over the year extending much longer than presently. The increasing temperatures are detected on both daily maximum temperature and daily minimum temperature. In addition, the area that will be warmer is estimated to expand and will thus cover larger areas than presently.

In terms of rainfall (precipitation), the model estimates indicate that precipitation will fluctuate in the first half of the century, but show then increasing trend during the latter half of the century. This increasing trend results from increasing rainfall intensity, as the length of the rainy season is estimated to be more or less the same as during the baseline decade (1980s). There is, however, differences between the estimated derived from the two climate scenarios, with the B2 scenario showing less clear changes in the precipitation in the future.

The maps summarising the results from the projections of two climate scenarios, ECHAM4 A2 and B2, are presented in the Figures below as well as in Annex B (Mekong Region) and Annex C (Mekong Delta). The maps show how temperature and precipitation are estimated to change from the baseline period of 1980s towards the middle of 21st century i.e. between 2010s and 2040s.

The estimated values for future temperature and precipitation in the region were then used as boundary conditions when looking at the hydrological impacts of climate change with the help of hydrological models (Chapter 3).

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<sup>2</sup>PRECIS is a regional climate model that was developed by Hadley Centre for Climate Prediction and Research. More information on PRECIS and its validation can be found in Annex A.

<sup>3</sup>The ECHAM climate model has been developed from the weather forecast model of the European Centre for Medium Range Weather Forecasts and the comprehensive parameterisation package that allows the model to be used for climate simulations. The model is a spectral transform model with 19 atmospheric layers. Numerous modifications have been applied to this model at the Max Planck Institute for Meteorology and the German Climate Computing Centre (DKRZ) to make it suitable for climate forecast. The current version is the fourth generation of the ECHAM climate model.

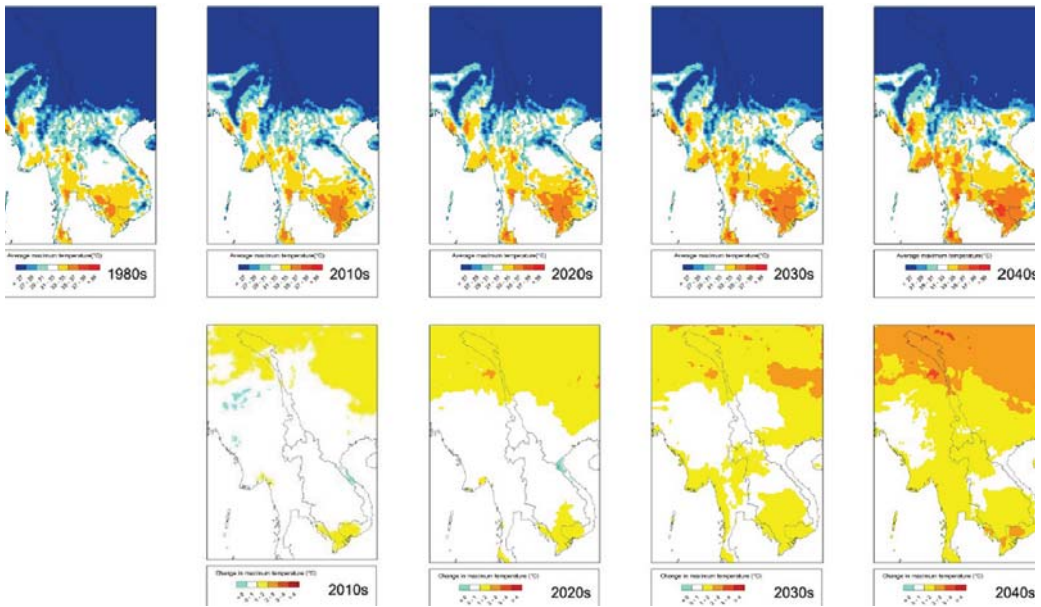


Figure 1. Average daily maximum temperature (top) and future change in maximum temperature compared to the baseline decade of 1980s (bottom) under A2 climate scenario.

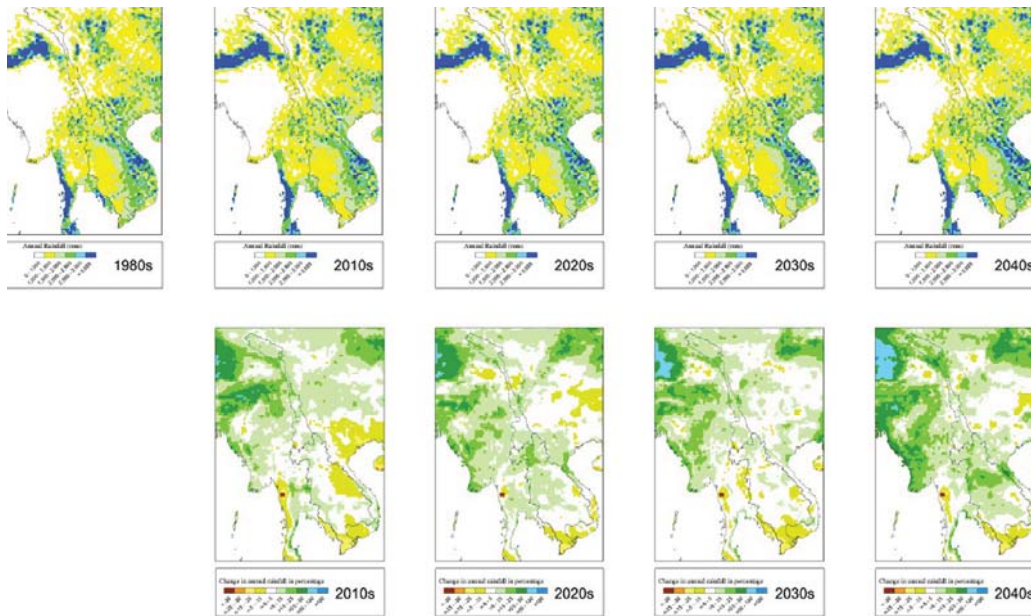


Figure 2. Average annual rainfall i.e. precipitation (top) and future change in the annual rainfall compared to the baseline decade of 1980s (bottom) under A2 climate scenario.

### 3 HYDROLOGICAL IMPACTS

This chapter summarises the key findings on the analysis of hydrological impacts of climate change. The findings are based on model simulation results on following scales:

- **Basin-wide hydrology:** basin-wide modelling was done with Variable Infiltration Capacity (VIC)<sup>4</sup> hydrological model that formed the boundary condition for the floodplain model in Kratie, Cambodia.
- **Floodplain dynamics:** floodplain modelling for the three study areas was done with the EIA 3D model that looked at the changes in different flood pulse characteristics.

The floodplain dynamics were studied in the context of three different climate-related scenarios having an impact on the hydrology of the study areas:

- **Changed basin hydrology (BASIN) scenario:** climate change -induced changes in basin-scale hydrology, to be felt in the study areas as regional / upstream impacts. Climate scenario SRES A2 was used for the simulations.
- **Sea level rise (SEA) scenario:** impact from increasing sea level rise
- **Cumulative impact (BASIN+SEA) scenario:** combining the impacts of changed basin hydrology and sea level rise

In addition to two specific study areas of the project, the Tonle Sap and the Mekong Delta, the results from the hydrological impact analysis are presented also in the third study area connecting the two, namely the Cambodian floodplains. Each of the three study areas has its specific characteristics:

- **Tonle Sap Lake of Cambodia:** including the area of the lake and its floodplains

- **Cambodian floodplains:** including the area from Kratie down to Vietnam-Cambodia border, excluding the Tonle Sap system
- **The Mekong Delta in Vietnam:** including the Vietnamese part of the delta. In the delta, the impact of sea level rise on salinity intrusion was also modelled.

The following time-scales are used in the simulations:

- **Baseline period/decade:** years 1995-2004
- **Climate scenarios** i.e. future decades:
  - 2010s (years 2010-2019)
  - 2020s (years 2020-2029)
  - 2030s (years 2030-2039)
  - 2040s (years 2040-2049)

Prior to the sections of the main results, a small introduction to the ecosystem functions is given. The more in depth view on the methods is presented in the project's Interim report<sup>5</sup> as well as in the annexes of this report.

#### 3.1 ECOSYSTEM FUNCTIONS

Wetlands, including floodplains, are important parts of rivers and other freshwater ecosystems. On a global scale, the area of wetlands is estimated to be between 2.0–5.3 million km<sup>2</sup> (Kvist and Nebel 2001) and 12.8 million km<sup>2</sup> (Millennium Ecosystem Assessment 2005), corresponding 3-9% of the total land area. The degradation and loss of wetlands is more rapid than that of other ecosystems (Finlayson and Spiers 1999; Millennium Ecosystem Assessment 2005). Maintaining the hydrological regime of a wetland and its natural variability is necessary to sustain the ecological characteristics of the

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<sup>4</sup> Annex D presents more information on VIC and its validation.

<sup>5</sup> Interim report is available at project's web-site: <http://users.tkk.fi/u/mkummu/water&cc>



wetland, including its biodiversity (Millennium Ecosystem Assessment 2005).

Wetland ecosystems that experience fluctuations between terrestrial and aquatic conditions are also called pulsing ecosystems, and can be described with the help of so-called flood pulse concept (Junk 1997). The flood pulse concept illustrates the highly productive floodplain environments and the ecology of pulsing systems, where the flood water integrates the terrestrial vegetation into the aquatic phase of the ecosystem. This interaction between the terrestrial and aquatic phases is the driving force of ecosystem productivity. The Lower Mekong

Basin (LMB) floodplain ecosystem forms a flood pulse system, where the annual monsoon floods, following the Mekong mainstream water level, sustain the high productivity of the area (MRCS/WUP-FIN 2007).

The Lower Mekong floodplains (Figure 3) receive more than 93% of the available water resources and 95% of the total suspended sediment flux from upstream, and the hydrology of the floodplains is thus dominated by the annual flood pulse that peaks usually at the end of September (Figure 4). The Lower Mekong floodplains, including both the Cambodian floodplains and the Mekong Delta,

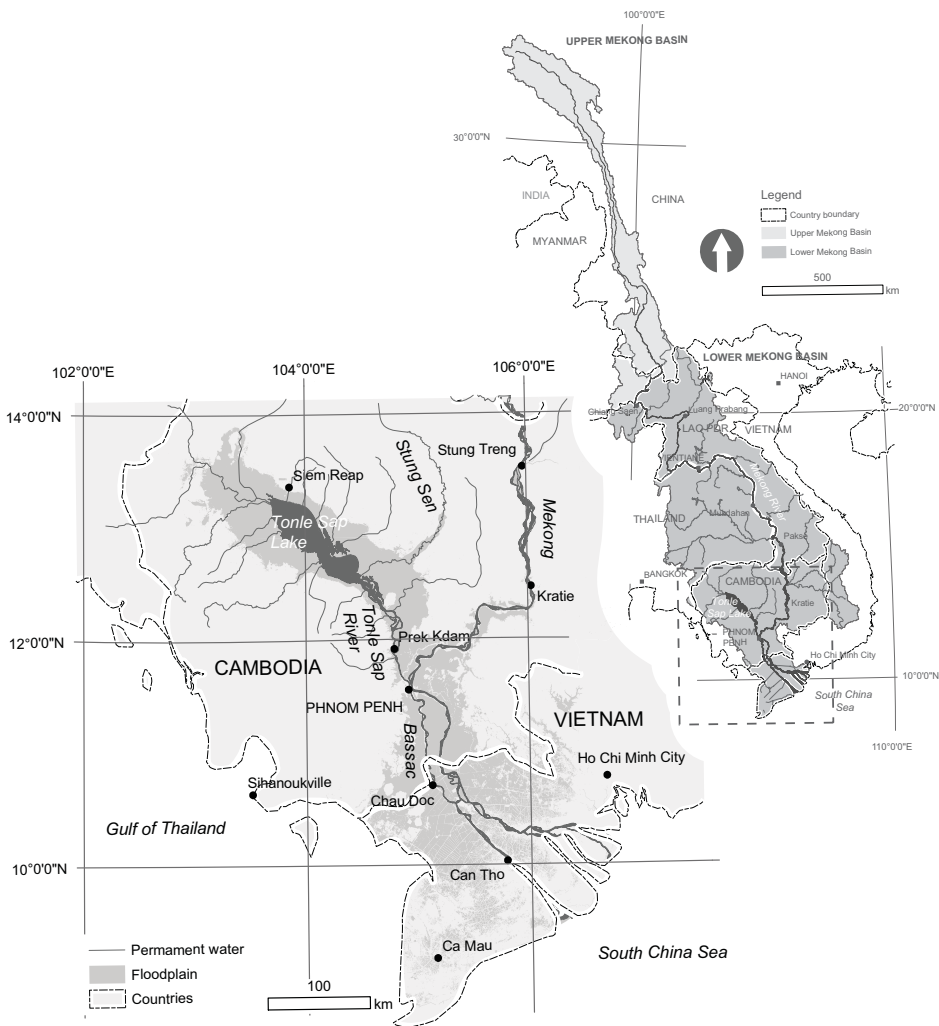


Figure 3. Map of the Lower Mekong floodplains.

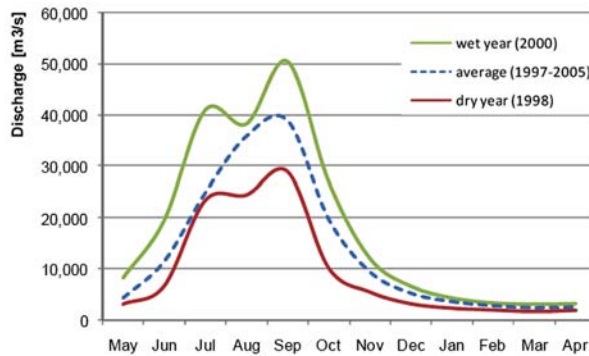


Figure 4. Monthly average discharge in Kratie.

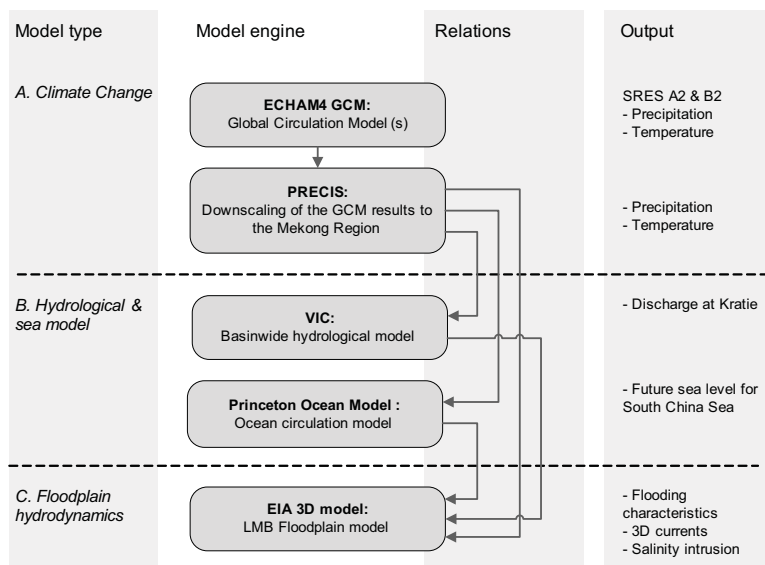


Figure 5. Schematic overview on the interactions between climatic, hydrological and hydrodynamic models.

are therefore directly dependent on the conditions of the Upper Mekong, and are also particularly vulnerable to any changes in the flow or sediment flux due to the upstream development. The Mekong floodplains are also socially and economically important for Mekong riparian countries and for Cambodia in particular. The floodplains provide livelihoods for millions of people and sustain one of the most intensive inland fisheries in the world.

### 3.2 MODELLING APPROACH

Impact of climate change on hydrological regime in the Lower Mekong floodplain system is determined

by the regional flow changes that result from climate change's influence on temperature and rainfall in upper parts of the basin. In addition to this change affecting basin hydrology, the impact of sea level rise is remarkable particularly in the delta. The impact of both of these climate-related phenomena to the hydrology of the study areas were modelled both separately and together. The schematic overview on the interactions between climatic, hydrological and hydrodynamic models is presented in Figure 5.

As explained above, the future climate projection data was simulated by ECHAM4 Global Circulation Model under two different climate scenarios (A2 and B2). The coarse scale climate projection was

then downscaled for the Mekong River region using PRECIS regional climate model (see Annex A) to provide higher resolution future climate projection. The downscaled data from PRECIS model was used as input to 1) basin-wide hydrological model (VIC) to simulate future river run-off, and 2) ocean circulation model (Princeton Ocean Model, POM), to simulate sea level change at the mouth of Mekong River under the influence of changing monsoon regime.

Result from VIC model (Mekong River run-off upstream the Lower Mekong floodplains) and POM (future sea level at the mouth of Mekong River) were together with the future climate data from PRECIS then fed into EIA 3D model for more detailed hydrological analysis for the Mekong River floodplain system.

### 3.3 CHANGES IN BASIN-WIDE HYDROLOGY

The basin-wide hydrological model VIC (Annex D) was able to simulate relatively well the seasonal changes in discharge as well as the year-to-year variations in total discharge and maximum discharge. The model, however, had difficulties to simulate the timing of the flood peak. However, when modelling the climate change impacts on hydrology, the relative differences between the scenarios are the most important measure to assess. Consequently, VIC can still be considered to be accurate enough to simulate the relative changes likely to occur under different climate scenarios.

Results from the basin-wide hydrological model indicate an increasing trend for the Mekong discharge at Kratie Station in Cambodia. In addition, there also seems to be higher fluctuation between the different years within each future decade (Figure 6).

VIC simulations indicate that the annual average discharge of the Mekong at Kratie is approximately 4.3% greater in the period of 2010–2049 compared to the baseline decade (1995–2004). Daily average discharges increase in the rainy season (May–October) and decrease in the dry season (November–April) during the latter future decades i.e. during 2020s, 2030s and 2040s. The opposite occurs in the 2010s, when the total discharge also decreases. Overall during the period of 2010–2049, daily average discharges are expected to increase by 5.14% in the rainy season and decrease by 2.18% in the dry season when compared to the baseline.

VIC simulations also suggest some changes in the monthly average discharges of the Mekong in the future (Figure 7). The average discharges of August, September and October increase noticeably for all the simulated future decades, whereas the discharges of April and May are expected to decrease significantly in the future. Other months show relatively small changes in monthly average discharges, and the hydrograph is therefore likely to shift slightly forward in the future.

In addition to average discharges, climate change has an effect on the extreme discharges i.e. lowest

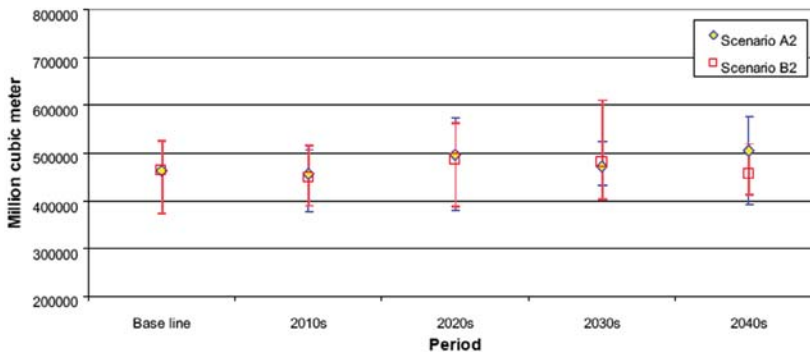
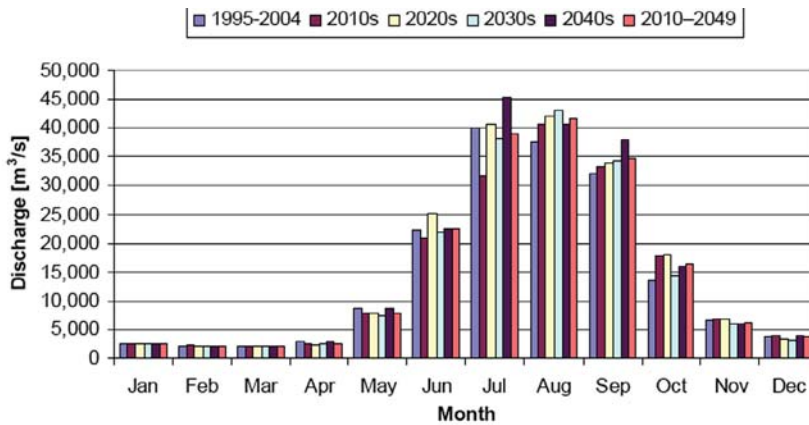


Figure 6. Comparison of annual discharge of the median year of the decade with highest and lowest flow of the decade based on future climate projection at Kratie Station.

**Table 1.** Total daily average discharges and daily average discharges in the rainy and dry season simulated by the VIC model for the Mekong at Kratie for the baseline period (1995-2004) and future decades.

	BASELINE 1995–2004	2010s	FUTURE 2020s	DECADES 2030s	2040s	2010–2049
Daily average Q [m <sup>3</sup> /s]	14.540	14.358	15.589	14.853	15.864	15.166
Change to baseline [%]		-1.25	7.22	2.15	9.10	4.30
Rainy season [m <sup>3</sup> /s]	25.750	25.333	27.919	26.580	28.457	27.072
Change to baseline [%]		-1.62	8.42	3.22	10.51	5.14
Dry season [m <sup>3</sup> /s]	3.319	3.368	3.248	3.113	3.258	3.247
Change to baseline [%]		1.49	-2.14	-6.22	-1.84	-2.18



**Figure 7.** Monthly average discharges of the Mekong at Kratie for the baseline period (1995-2004) and for future decades.

and highest annual discharge within each decade. To describe the changes of these extreme years, we use the concept of water years, and consequently, of driest water year and wettest water year<sup>6</sup>. The VIC simulations show that the discharges in both the driest and wettest water years of each future decade between 2010 and 2049 will increase compared to the baseline decade of 1995-2004. The average increase for driest water year is 5.92% and for wettest water year 2.18% (Figure 8). The driest water years of each simulated future decade are wetter than the driest water year of the baseline period of 1995-2004. By contrast, the wettest water years of simulated future decades show greater variation as

they are either drier or wetter than the wettest water year of the baseline period. The wettest water year in the period of 2010–2049 had a 7.36% greater annual discharge than the wettest water year in 1995–2004.

The monthly discharges of the Mekong at Kratie in the driest and wettest water years of each decade are presented in Figure 9 and Figure 10. In terms of the driest water years, the dry season discharge (November–April) and the wet season discharge (May–October) increase on average by 20.6% and by 5.66% in 2010–2049 when compared to the baseline. In the wettest water years of each decade,

the dry season discharge decreases on average by 24.8% and the wet season discharge increases on average by 5.8% compared to the baseline.

### 3.4 CHANGES IN LOWER MEKONG FLOODPLAIN

The EIA 3D floodplain model (Annex E) was used to model the climate change impacts on the Lower Mekong floodplains, including all three study areas i.e. Tonle Sap area, Cambodian floodplains and the Mekong Delta (Figure 3). For each decade three different water years were modelled:

- driest water year
- average water year
- wettest water year

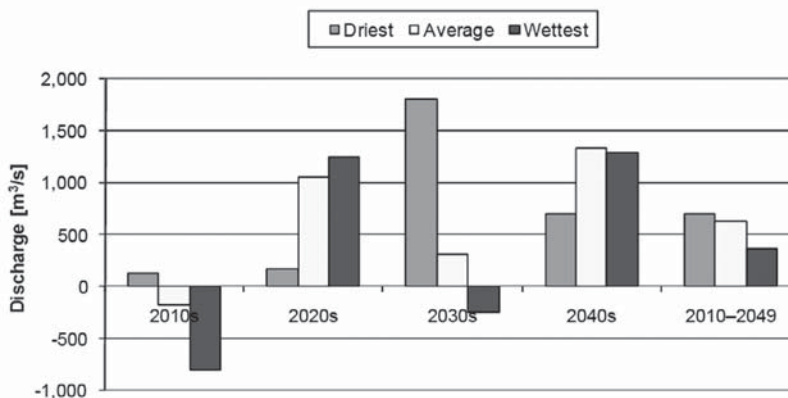
The spatial extent of flood pulse can be described through water level and flooded area. These two variables are related to each other and are thus discussed together in this section. Water level is defined as the elevation of water surface above the mean sea level (amsl) at a given point at a given time, while flooded area indicates the total area that

is inundated at a given time. Daily flooded areas can be summed up to obtain the annual cumulative flooded area, which indicates how extensive inundation has been during different years.

#### 3.4.1 Changes in floodplain water levels

In all three study areas, annual average water level is projected to increase in all the scenarios (Figure 11). Changed basin hydrology (BASIN) and cumulative changes (BASIN+SEA) caused the most significant absolute increase in the Tonle Sap floodplains, but the relative increases were more equal between the different study areas. Increases were 0–4% for the sea level rise (SEA) scenarios, 1–4% for changed basin hydrology (BASIN) scenarios, and 2–7% for cumulative (BASIN+SEA) scenarios.

The average low water level is estimated to increase in all study areas in eight scenarios out of nine, the only exception being the changed basin hydrology scenario for the driest water years (Figure 11). Relative changes are -3–17%, differing significantly between the three study areas. Sea level rise (SEA) increases the average low water level in the Delta by 12–14% in the average and driest years, whereas its effect in the Tonle Sap floodplains is at 0–1% much less significant. The strongest changes occur during



**Figure 8.** Annual discharges of the Mekong in the driest, average and wettest water years of the baseline period and future decades.

<sup>6</sup> Water year is defined based on the flood timing (instead of the Western calendar year), and starts therefore on May 1st and ends on April 30th. The term ‘driest water year’ therefore describes the years that are driest (average annual flow is lowest), ‘wettest water year’ describe the years that are the wettest (average annual flow is highest) and ‘average water year’ the average years within each of the simulated future decades.

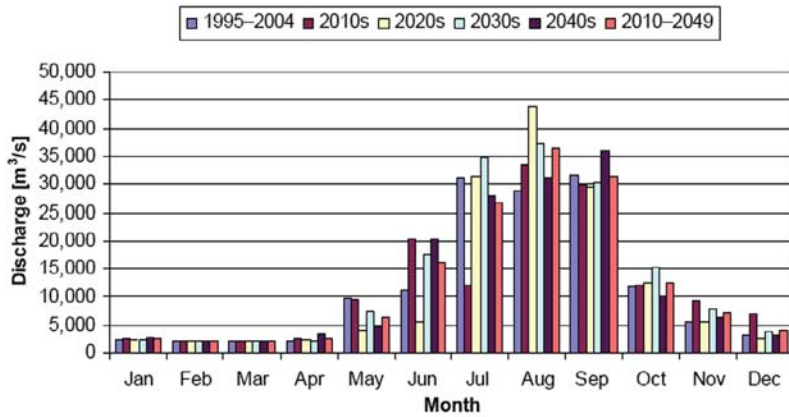


Figure 9 Monthly discharges of the Mekong in the driest water years of the baseline decade (1995-2004) and of each future decade. Also the average values for monthly discharges in the driest water years during future decades (2010-2049) are shown.

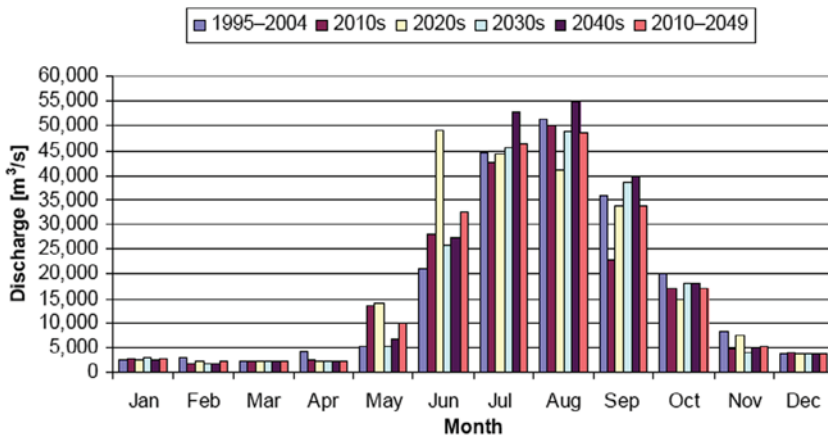


Figure 10 Monthly discharges of the Mekong in the wettest water years of the baseline decade (1995-2004) and of each future decade. Also the average values for monthly discharges in the wettest water years during future decades (2010-2049) are shown.

the wettest years of the changed basin hydrology (BASIN) and cumulative (BASIN+SEA) scenarios. By contrast, these scenarios demonstrate the only decreases in average high water level (Figure 11). Sea level rise (SEA) barely affects the average high water level (0–1%), whereas the effects of changed basin hydrology (-4–4%) and cumulative impacts (-4–5%) are clearly more notable. The relative changes in average high water level are very similar in all three study areas.

Comparison between the three study areas shows that the effects of sea level rise (SEA) are most notable in the Mekong Delta, and decrease in the more upstream areas of the Cambodian floodplains

and the Tonle Sap area. By contrast, the impacts of changed basin hydrology (BASIN) are felt most strongly in the Cambodian floodplains and the Tonle Sap area. It is also important to note that sea level rise causes greater changes in average water level in the driest and average years compared to the wettest water years, as its importance is greater during the years that are less wet. For the cumulative (BASIN+SEA) scenarios, the relative changes were the greatest in the Mekong Delta.

### 3.4.2 Changes in flooding characteristics

The model simulations show an increasing trend in the annual maximum water depth and

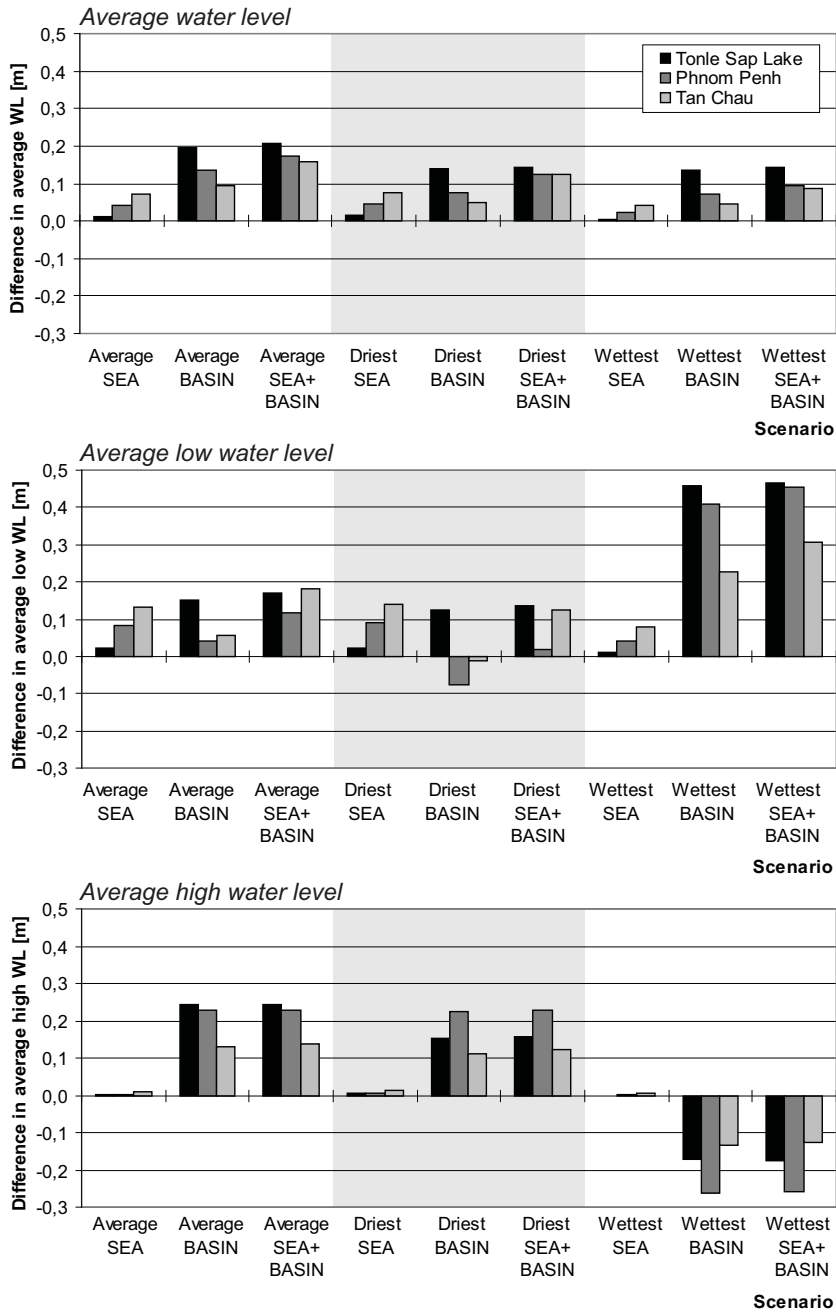


Figure 11. Projected differences for average water level (top), average low water level (middle) and average high water level (bottom) compared to the baseline period of 1995-2004.

flooded area during the average and driest water years. Similarly clear trend is not visible in the wettest water years, however, as they show either decrease or small increase in these characteristics (Figure 12). The annual maximum water depth and flooded area differ by -3–12% and -3–14%, respectively, from the values of the baseline period. The most significant changes are projected for the average water years.

The absolute changes in maximum depth are the greatest in the Tonle Sap area, but the relative changes are higher in the other two study areas i.e. the Cambodian floodplain and the Mekong Delta. Flooded area is estimated to have the greatest absolute and relative changes in the Cambodian floodplains (-3–14%) and the smallest relative changes in the Mekong Delta (0–3%). It is important to note that the changes in simulated maximum

depth do not always correspond to changes in simulated flooded area, particularly in the Mekong Delta, as the relation between water depth and flooded area varies according to the location.

### 3.4.3 Changes in the Tonle Sap flood pulse

The Tonle Sap area is one of the most important and critical parts of the Mekong system due to its unexceptional water regime, unique flood pulse – dependent ecosystem and high fish production (MRCS/WUP-FIN 2007, Keskinen et al. 2007). For the same reason, it is also considered as a particular vulnerable area for potential changes in the Mekong’s flow. For this reason, the potential hydrological impacts of different climate change scenarios were studied with a specific detail for the Tonle Sap area. The results of this analysis can be found from Annex F. More detailed analysis of the impact on Tonle Sap

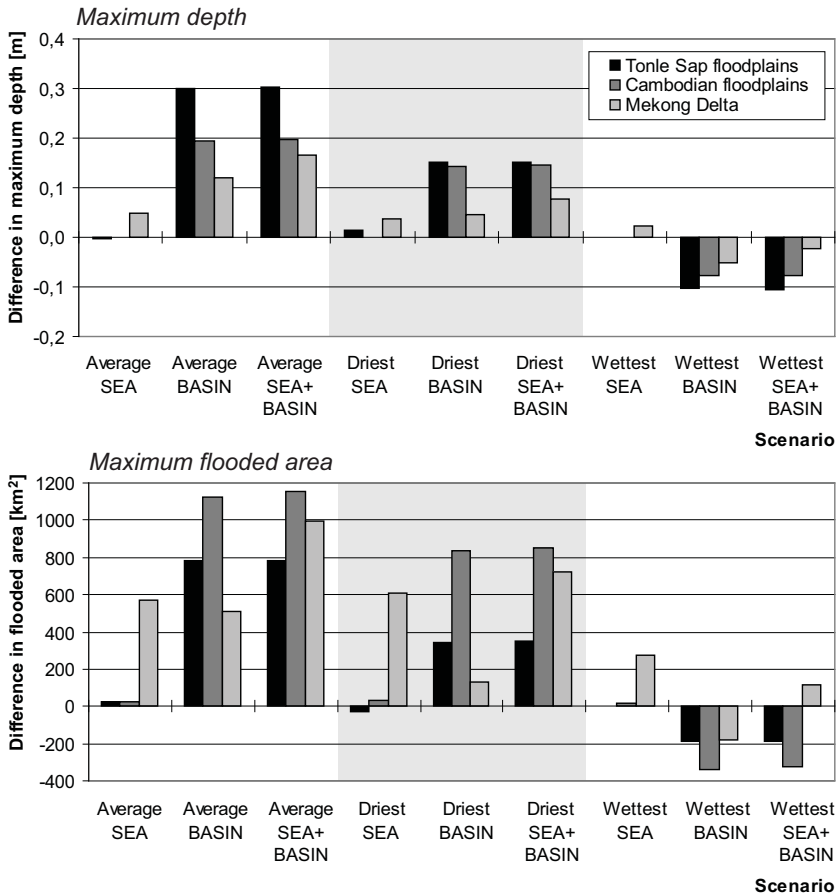


Figure 12. Differences in maximum depth (top) and flooded area (bottom) compared to the baseline period of 1995-2004.



flood pulse can be found from the Master's Thesis done related to the project (Västilä, 2009).

#### 3.4.4 Comparison to other studies

The literature review found no other studies that would have given numerical estimates about the impacts of climate change on the characteristics of the Tonle Sap flood pulse. However, the qualitative results of Eastham et al. (2008) are largely similar to the results of this study: they state that the annual maximum water level and maximum flooded area of Tonle Sap Lake will increase and that water level will rise earlier and flood duration will increase in the near future. Eastham et al. (2008) assess that the increases in maximum water level and maximum flooded area are 2.3 m and 3'600 km<sup>2</sup>, which differ notably from our results of 0.6 m and 1000 km<sup>2</sup>. This difference can be partly explained by the differences in the water level–area–volume relations, models and methods between the two studies.

The results of this study are also in accordance with the more general studies on climate change impacts

in the Mekong Basin, which estimate increases in annual and rainy season precipitation, runoff and discharge in the first half of the 21<sup>st</sup> century (Nijssen et al. 2001; Eastham et al. 2008; Hoanh et al. 2004, ref. Bates et al. 2008). Although the hydrodynamic modelling did not focus on dry season, the climate change simulations of SEA START RC predict decreasing dry-season discharges for Kratie and decreasing dry-season precipitation for Tonle Sap area. Other studies concerning dry-season changes show partly differing results: while Nijssen et al. (2001) and Hoanh et al. (2004, ref. Bates et al. 2008) state that the driest months of the year will become drier, Eastham et al. (2008) conclude that runoff will increase in the dry season months.

The studies concentrating on the end of the 21<sup>st</sup> century have also obtained relatively differing projections concerning the average annual and monthly discharges (ADB 1994, ref. Bates et al. 2008; Arora & Boer 2001; Kiem et al. 2008). All in all, it seems that the results of this study are mostly in line with similar kind of studies on climate change impacts in the region.

## 4 LIVELIHOODS & LOCAL ADAPTATION STRATEGIES

The analysis of water-related livelihoods, their resilience and local adaptation strategies complemented the analysis of climate scenarios and related hydrological and hydrodynamic changes. This was done in order to ensure more comprehensive view on climate change adaptation as well as to link the modelling results better with the actual realities at the local level.

The diagnosis of livelihood-related impacts was implemented slightly differently in the two study areas of the Tonle Sap and the Mekong Delta. In the Tonle Sap, the analysis built on field research in the villages, making use of key-informant interviews in six study villages in two areas crosscutting the floodplain. The focus of the analysis was thus on specific contexts as well as different adaptation strategies at the local level.

In the Mekong Delta, the analysis built on spatial analysis as well as on the inputs derived during the stakeholder consultation workshop organised in Can Tho in March 2009. The focus in the delta was thus on bit more macro-scale issues, including the potential impacts to different geographic areas and major livelihood sources, with particular emphasis on agriculture and aquaculture. The results from the two study areas are next discussed in more detail.

### 4.1 TONLE SAP

#### 4.1.1 Introduction

The livelihoods analysis in the Tonle Sap area aimed to link the changes in the water resources and environment to the realities of the people living in the area, with a focus on water-related livelihoods. Climate change may be one reason for these changes in the future, but also other issues such as hydropower development and institutional issues are likely to have an impact – and on a much more immediate timescale.

The main livelihood strategies in the Tonle Sap area are rice cultivation and fishing: both of these occupations are highly dependent on natural

resources, and are influenced by the dynamic hydrology of the lake, notably the flood pulse system with its remarkable but yet relatively regular seasonal variation. A large proportion of the population in the area is living in poverty, and is therefore particularly vulnerable to changes in the environment and in the availability of different natural resources.

The theoretical approach of the livelihoods analysis was based on the resilience theory with additional inputs from the sustainable livelihoods approach. The on-going discussion on climate change adaptation was also considered. The resilience thinking notices the dynamic interconnections between the ecological and social systems. It focuses on the magnitude of change that the system can cope with while still being viable, and to the ways in which social systems are capable of adapting to these changes. The sustainable livelihoods approach focuses on poor people, and defines the different assets which affect their ability to cope with shocks and stress. The methods used in the analysis were review of previous research and literature on study area and themes, and field research and interviews conducted in the Tonle Sap area and in Phnom Penh during September 2008.

The first objective was to assess the different impacts that the changes in the environment and water resources are likely to have on the livelihoods of the people living in the Tonle Sap area. Related to this, the aim is also to define the changes that have already taken place or are on-going and have had effect on people's lives. Special emphasis was placed on determining the groups that are most vulnerable to the changes.

The second objective was to assess the resilience of the livelihoods to such changes; in other words their capacity to cope with various shocks and stresses that place pressure on their everyday life. The Tonle Sap area experiences a great natural variation in the environment on a seasonal basis due to the flood pulse from the Mekong River. The local livelihoods are already well adapted to the resulting seasonal changes, which could suggest that their inbuilt resilience towards environmental

pressure is relatively high. The question here is, however, whether the changes induced by climate change or other major changes, will multiply the effect of other stress factors to such an extent that it will force the social and environmental systems to a point where they cannot bend under the pressure any further. Such a situation may result in unexpected and substantial changes such as the collapse of fish stocks, which may then have drastic impacts on the livelihoods.

Related to resilience, the adaptation strategies that people living in the study area utilise in coping with different changes were looked at, concentrating on so-called autonomous strategies that they have used to cope with environmental changes and risks in the past. The objective here was to assess the usability of such strategies in planning future adaptation strategies.

More information on the analysis in the Tonle Sap can be found from the Interim Report of the project (TKK & SEA START RC, 2008) as well as from the Master's Thesis done related to the project (Nuorteva, 2009).

#### 4.1.2 Field studies

The field research was carried out in two provinces, Siem Reap and Pursat, with three study villages in each province. The study villages were chosen so that they formed a cross-cut through the floodplains from the national roads towards the Tonle Sap Lake, according to the topographic zoning of the area (Figure 13). This approach helps in comparing the circumstances in villages with different livelihood and occupational backgrounds. It also offers a means of connecting the environmental factors, particularly the ones related to the water resources, to the social and livelihood aspects.

The main method used in the field research was key-informant interviews with three to four informants from each village. Usually the first interview was conducted with the village chief or deputy chief in

order to get a general understanding of the village composition, livelihood patterns, level of income and any specific features of the village, as well as his personal views about the research topics. The other two informants were selected so that they represented different genders, ages and livelihood sources. In addition, at least one of them represented the poorer population of the village<sup>7</sup>. The interviews were conducted in a loosely semi-structured form following specific pre-determined themes and topics, but still leaving space for free-flowing discussions. The informants were encouraged to elaborate on their answers, and to explain the reasons and meanings behind their views. Observation walks around the study villages were also carried out in order to get a better idea of the village, its surroundings and livelihood structure.

#### 4.1.3 Findings from the field studies

##### Present and future challenges

Key-informants have noted changes in the flood patterns and their intensity, and they have in many occasions increased the pressure on livelihoods. Unusually high floods with severe effects were reported during the past decade. These have destroyed rice harvests and houses, causing the people to face food shortage. Intensive droughts pose another serious challenge for the rural livelihoods. The problems during droughts were usually related to scarcity of available drinking water and deterioration of water quality in rivers and ponds. Agricultural households that rely on irrigation during the dry season have also had problems due to inadequate supply of water during droughts.

Heavy storms, accompanied by strong winds, rain, and high waves, are one potential source of problems, and they are likely to be intensified by climate change. The storms may destroy houses, boats and crops, prevent people from practicing their livelihoods (e.g. going fishing or to the rice fields), and even cause deaths. One of the study villages had faced a serious storm in 2005 which destroyed or damaged 52 houses; most of these were those owned by the poor.

<sup>7</sup> The poor doesn't here refer directly to monetary assets or economic status of a person/household, but the poor were defined more generally to be those people who have less assets and/or access to them (including physical and financial but also human, social and natural assets) and whose living standard is therefore lower than on average within the village. The poorer key-informants were selected based on discussion with first key-informant and other villagers.

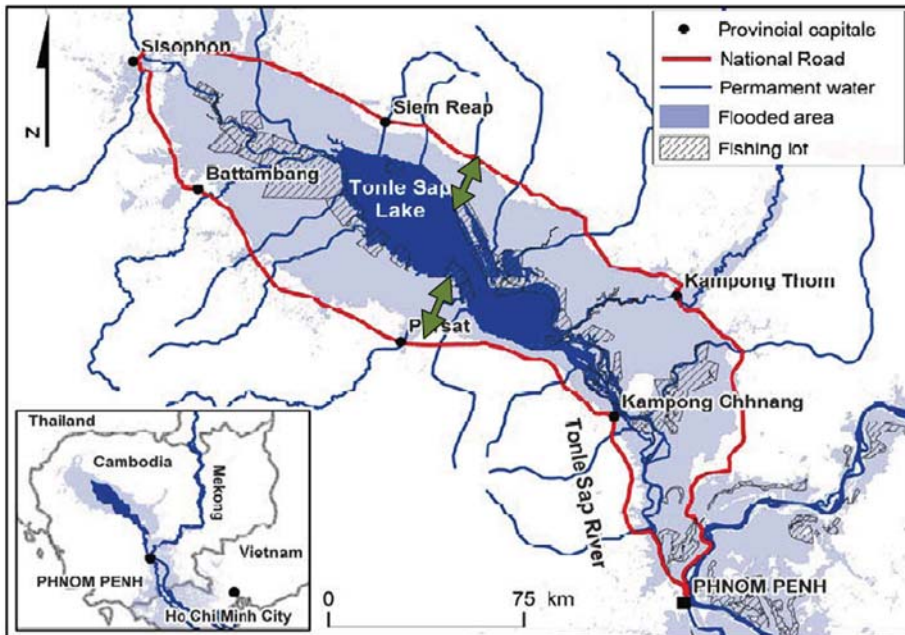


Figure 13. Map of Tonle Sap area indicating with green arrows the location of the two cross-cuts where the field studies were carried out.

Decreasing soil quality was mentioned as one future challenge in the agricultural areas. Decreasing water quality in ponds and rivers, caused by local and/or upstream disposal of chemicals and other waste, was noted in various parts of the floodplain. This can result in increasing health problems, in difficulties on obtaining clean water for household consumption and in negative impacts for fish and other aquatic animals and plants.

One significant challenge in the study area is the decrease in fish catch, caused partly by the use of illegal fishing techniques as well as increasing fishing pressure in the lake area. The lack of efficient law enforcement to prevent the illegal fishing practices – particularly at larger scale – adds to the problem. The reduction of habitats for fish reproduction and maturation due to deforestation of the flooded forests worsens the situation. The loss of seasonally flooded forests and scrublands may be further intensified in the future due to hydrological changes in the flood pulse. Built structures in the floodplains and lake area, such as irrigation structures and roads, may also affect the seasonal migration of the fish and the flow of

fish larvae, having impacts on the fish stocks and changing flood patterns.

#### Impacts on livelihoods

The potential environmental challenges affect the people in the villages at different ends of the floodplain in different ways – the specific impacts are usually closely related to the respective livelihood strategies. High floods may destroy the rice harvest in the agricultural villages, and may also cause damage to the stilt houses in the fishing villages closer to the lake. Floating houses next to the lake are generally well adapted to such floods and may remain highly unaffected. However, the floating houses are more vulnerable to impacts of storms, strong waves and wind, which may prevent them from going fishing, cause damage to houses and other assets, and even force them to relocate their village to a safer area. The already poor households are most likely to suffer the worst impacts, as their houses are generally more fragile and vulnerable to extreme weather conditions, and they have fewer assets for fixing the possible damage.

Difficulties in getting clean drinking water during exceptionally dry periods can affect all the villages

regardless of their livelihood, even though for the fishing villages located very close to the lake the situation may be better, as they may be able to use water directly from the lake. On the other hand, the quality of the lake water for drinking is low compared to that of groundwater which is better available higher up in the floodplains.

Decreasing aquatic productivity of the lake, fish in particular, obviously has the most direct impact on the fishing villages, where almost all villagers rely on fishing for their livelihood and food. In many cases the most vulnerable population can be found in the fishing villages. Fishing seems also to function as a last resort for those who may not for example be able to attain land for agriculture, such as the landless poor or ethnic minorities like the Vietnamese. However, as fish provides the main source of protein for a large part of the Cambodian population and the Tonle Sap system provides a remarkable part of the country's fish catch, the impacts from potential reduction in aquatic production are likely to extend much further. Besides, even though the amount of households with fishing and fish-related activities as the main livelihood income is rather small compared to rice cultivators, fishing is very important as a secondary and complementary source of livelihood for others as well.

### Local adaptation strategies

If faced with rice shortage due to shocks to their livelihoods, the villagers with medium or high income may have some savings to which they can resort, while the poor can borrow money from middlemen, neighbours or relatives. Not all poor informants, however, were willing or able to borrow money, and some would resort to selling their assets, such as a buffalo or a boat, in case of emergency. This can provide them with fast, short-term income, but it can also decrease their general living standard in the long run as well as their general resilience towards challenges in the future. Most of the informants mentioned receiving external aid in the form of rice portions to last for a week or two as an immediate response to the shock.

One strategy for coping during hard times, mentioned in all the villages along the floodplains, was finding short-term paid employment. The source of employment varies according to the

livelihood background: in fishing villages the poorer population may find employment in fishing lots (large-scale fishing areas), while in agricultural areas the employment is usually found from the factories or from the rice fields of more affluent neighbours. Some informants, usually fishers, mentioned collecting edible plants such as water lilies and morning glory as means to get some extra income during difficult times.

Migration to find work in the nearby towns or cities, often sending one's children to search for work, seems to be a popular long-term backup plan in all study villages. Yet, most informants would prefer to stay in their home villages as long as the circumstances allow it. Extensive migration after a widespread environmental shock would also place serious pressure for towns and cities.

Some of the more concrete responses to environmental challenges are related to infrastructure and other technical means. These include for example raising the houses to protect them from high floods, building dykes and culverts, changing to different, more flood-resistant rice varieties, increasing household food stocks, and moving livestock to higher grounds.

Based on the research findings, categorising the adaptation strategies to autonomous and externally-initiated ones is not very straightforward. It seems that most of the mentioned strategies were initiated by the villagers themselves. They can, however, be stimulated by examples from other villages or households, or by the local circumstances as is the case with different employment opportunities available. Few of the adaptation strategies (excluding direct food and other aid in case of serious disasters such as droughts) mentioned by the informants were clearly brought from the outside e.g. by government actors or NGOs. This may imply that until now, such efforts have not been pursued, or if they have, the villagers have not assumed proper ownership of them.

### Factors limiting resilience

The people and their livelihoods in Tonle Sap area are generally well adapted to the seasonal changes due to the flood pulse: the remarkable but yet rather regular seasonal variation is actually supporting the most important livelihoods in the area (rice

cultivation, fishing). At the same time, however, the people and their livelihoods are vulnerable to significant changes in this regular flood cycle.

The findings from our field research indicate that particularly the resilience of the poor population to unusual environmental changes is already now relatively weak, and is not likely to be increasing. The situation seems to be particularly bad in the fishing villages, where the poorer key-informants were not very hopeful about being able to sustain their livelihoods in the face of future challenges. Some felt that there are no possibilities of broadening into other livelihood sources such as agriculture, especially if the village is located close to the lake, where no land is available for agriculture. In agricultural villages, the challenges caused by negative impacts from environmental changes are further intensified by the increasing population in the area coupled with unavailability of new agricultural land. In addition, several informants throughout the floodplains were experiencing problems due to the recent rise in the prices of rice and other commodities, and were worried about the situation getting even worse in the future.

One issue that increases the vulnerability of the livelihoods in Tonle Sap area to outside stress is the observation that even though the people may have supplementary occupations, usually the main livelihood strategy – typically rice cultivation or fishing– within one village is very uniform (see also Keskinen 2006, 2003). Recovering from negative impacts to a specific livelihood source might therefore prove very challenging in situations where majority of the villagers are affected at the same time. This would probably impair the security provided by social networks, and increase pressure on the natural resources even further as large amounts of villagers would rely on secondary livelihood sources simultaneously.

At the same time internal differences between the households within a village were observed as well. The poorest households seemed to be clearly the most vulnerable in all study villages due to their weaker asset base and narrow livelihood and income opportunities.

Related to this, the research findings indicate that inequality in distribution of wealth as well as in the

access to the resources and assets seems to have intensified in the study villages during past years. Most of the poor respondents noted that their living standards have gotten worse during the past decades, while majority of the better-off informants considered their living standards improved during the same period. This finding was the same in both agricultural and fishing villages.

### **Strategies for increasing resilience**

Several of the adaptation strategies mentioned by the key-informants were related to general increase in living standards, which will result in increased resilience. Examples given by the informants indicate that involvement in secondary livelihoods and generally in multiple livelihood strategies have enabled them to increase their assets base, and as a result they feel more positive about their future and resilience to possible changes. Initiating supplementary livelihoods was in fact brought up by several informants as a strategy for increasing their own livelihood opportunities.

The specific strategies mentioned were usually closely linked with the informants' livelihood sources. For example in the villages closest to the lake, which rely heavily on fishing as a main livelihood source, many hoped to broaden their livelihood base into fish raising. In the agricultural villages, raising livestock and broadening cultivation to other crops such as vegetables and other rice varieties were considered as viable strategies to decrease the respondents' dependency on just one source of income. Starting small businesses was also mentioned by several respondents in both fishing and agricultural villages, but mostly in the Siem Reap province and not so much in Pursat. Several informants in Siem Reap were interested in initiating small businesses in order to get their share from the growing tourist industry in the area.

Other viable measures that have enabled the respondents to engage in supplementary livelihood sources and to improve their living standards, have been microcredit schemes and saving groups, initiated mainly by different NGOs. These enable the people to acquire capital for initiating supplementary livelihood strategies, for example chicken raising, or for enhancing their capacities in their present livelihoods, for example by purchasing new fishing

gear or new rice varieties. Supplementary livelihood sources were seen to help to increase the resilience towards shocks and stresses, as they decrease the dependency on only one livelihood source and increase the possibilities of building broader and more solid asset base. Saving groups also allow the people to decide themselves what they want to use the funds for, and they thus seem to encourage autonomous adaptation and resilience.

#### 4.1.4 Summary of the livelihood analysis

The people living in the Tonle Sap area and its floodplains are used –and adapted– to great seasonal variations in their environment and water resources. This is due to prominence of the Tonle Sap’s flood pulse system that results in remarkable variations in both water level and lake area between dry and wet seasons: during the rainy season the water depth in the lake rises from mere 1 meter even up to 10 meters, while the lake’s surface area quadruples and extends the lake over vast floodplains consisting mainly of flooded forests, shrubs and rice fields (MRCS/WUP-FIN 2003).

It is important to note, however, that the Tonle Sap flood pulse system is despite its remarkable variation nevertheless relatively regular, and people are adapted to this “regular variability”. Thus, the resilience towards seasonal changes has its limits, and if e.g. water level is then much higher than usually –like was the case in year 2000–, the adaptation capacity can actually be fairly limited.

Adaptation capacity seems to be worse for the population groups which rely very strongly on only one livelihood source, as is often the case for the poorest households in both fishing and agricultural villages. Broadening the livelihood base through supplementary occupations is especially challenging in the fishing villages located close to the lake on the floodplains, as there is usually less possibilities for livelihood diversification and secondary and tertiary occupations. The poorest groups’ already low living standards and asset-base intensifies their vulnerability to challenges to their livelihoods. In the case of more serious and widespread environmental challenges, the impacts may affect a much larger share of the population in rural Tonle Sap. This is likely to lead to a deepening of

poverty in the area as well as increasing migration to towns and cities.

One straightforward way to increase the resilience is therefore to raise the general living standards in the area, and especially those of the most vulnerable and poorest groups. Broadening the livelihood base with supplementary income sources is one option to do this, but the initiative for this should come from the people themselves in order to be sustainable and viable. The respondents have several ideas about the sort of activities through which they could improve their future livelihoods. Microcredit schemes and saving groups could be one useful channel to enable these ideas to be realized, and are worth developing further.

Building and strengthening the autonomous adaptation strategies to cope with environmental pressure is therefore one central approach for improving the resilience of people living in the Tonle Sap area. The current autonomous adaptation strategies are largely responsive i.e. they are applied mainly after the occurrence of major shocks. They can, however, also be used to highlight existing strengths and weaknesses and thus to recognise future development needs. The impacts of climate change are likely to be similar of previous, unusual climatic conditions, and studying past responses and adaptation measures is therefore crucial for developing efficient future adaptation.

Enhancing general level of development in the area, for example by increasing access to education, health services and clean drinking water, are also important issues in increasing resilience towards both shorter-term shocks and longer-term stresses. Improving access to markets for example by developing the road network and repairing old roads can also improve the livelihood situation.

The massive governance challenges in the Tonle Sap area and entire Cambodia also reduce the resilience and adaptation capacity, particularly among the poorest and most vulnerable groups. While the people’s well-being and livelihoods are closely related to different natural resources and assets –most importantly land and fishing areas–, the access to and control of these resources is still unequal. The powerful, well-connected groups have usually

easier access to different resources, and they also have better means to cope with changing regulations and requirements from government actors such as fisheries officials (see e.g. Keskinen et al. 2007).

Finally, the research results point out that the awareness in rural Tonle Sap area of the causes, impacts and timescales of climate change seems to be rather limited. While there are also more immediate concerns in their lives, increasing the people's knowledge of possible future changes should be focused on in order to build a basis for long-term adaptation capacity. Furthermore, an accurate early warning system of hazards such as storms and unusual floods is still inadequate, particularly in terms of communication to local level. Developing well-functioning warning systems is crucial in order to allow the people and institutions at different levels a possibility to make necessary preparations, and thus to avoid at least some of the negative impacts.

## 4.2 MEKONG DELTA

### 4.2.1 Introduction

The analysis of livelihoods and local adaptation capacity in the Mekong Delta built on spatial, macro-scale analysis of climate-related impacts as well as the input achieved from the stakeholder consultation organised at the Can Tho University in March 2009. The consultation workshop brought together around 30 key-informants from 5 provinces of the delta; An Giang and Dong Thap (located in the flood prone area in the upper Delta), Can Tho (located in the middle parts of the delta), Bac Lieu and Tra Vinh (located on the coastal areas). The objective of the consultation was to present the initial findings of the climate scenario analysis as well as to assess the concerns and adaptation possibilities related to the future climate scenarios and related changes in the delta's flood regime. Specific focus of the discussion was on the delta's agricultural activities, particularly on rice cultivation.

The Mekong Delta of Vietnam covers an area of around 39'200 square kilometres with total population of over 16 million (SIWRP & VNMC 2003). The delta is a low-level plain not more than three meters

above sea level at any point, and it is crisscrossed by a maze of canals and rivers that satisfy agricultural needs and serve as means of transportation and communication. The life in the delta is greatly affected by the floods, tides, saline water intrusion from the sea and alluvium-rich floods of the Mekong. These benefits derived from the water are a crucial part of the conditions that provide high agricultural productivity and enable the delta to sustain very high population densities (MRCS/WUP-FIN 2006). The Delta is known for the vast rice fields that together with other agricultural and aquacultural products make up the core of this region's economy. Agriculture and particularly rice cultivation is of major importance to Vietnam: approximately 70% of the labour force works in the sector, and the country holds currently around 10% of world rice market. Half of the national production and 70% of the exported rice comes from the Mekong Delta that is therefore commonly described as the rice basket of Vietnam.

Since the end of the 1980s, Vietnam has changed its economic policy towards market-oriented economy and has seen a rapid economic growth. Particularly rice production has gained important achievements, and Vietnam has developed from a food-deficit country to one of the largest rice exporters in the world. However, rice production faces also a lot of difficulties, including natural disasters and lack of capital. Furthermore, fluctuation of world market prices for rice influences directly the rice production in the Delta, and the weaknesses of rice exporting system restrains domestic production and reduces profits at both household and national level (Nguyen and Kawaguchi 2002). Global warming, which will induce change in climatic pattern as well as flood regime in the Mekong Delta, will add more pressure to the livelihood of the people in the delta area.

### 4.2.2 Key concerns on climate change and changing flood regime

The results from the stakeholder consultation show that key concerns related to climate change and consequent changes in flood regime in the delta are related to agricultural activities and rice cultivation in particular. Some of the key concerns discussed in the consultation included estimates for higher temperatures and longer summertime, as this would affect the rice yields through interference of the maturity of rice plant.



In addition, irregular rainfall was considered as a serious threat for the agriculture, and particularly for the important summer-autumn rice crop season. This crop season starts in April and its harvest time is in August. Concerns related to irregular rainfall were mainly related to the dry-spell events during the early phases of the crop season i.e. around June-July. This is also the time when growing rice requires plenty of water.

When considering these particular factors, the results from climate scenarios indicate that changing climate will pose a clear risk for the delta's rice production system. This is visible in the spatial illustrations that show that rainfall during the early period of summer-autumn rice crop season would reduce throughout the Delta (Figure 14 - Figure 17).

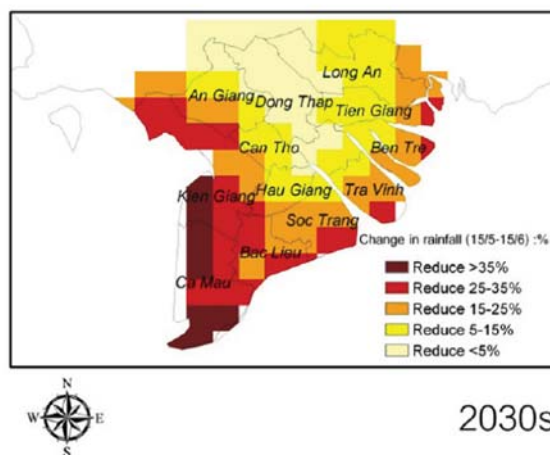
The events of dry-spell, defined as the period of 5-day with total rainfall less than 100 mm, are also likely to increase in the future. This is likely to result in higher cost for rice production, as farmers will have to pump water from different sources –either from canals and ponds or from the ground– to maintain their paddy. In addition, changes in daily maximum temperature as well as in extreme hot periods will affect rice yields as they will affect the growth rate and maturity of rice plant. It is also important to note that climatic changes also have an effect on animals, thus potentially increasing the abundance

of plant pests such as grasshoppers as well as affecting the well-being of livestock (particularly high temperatures).

Estimated changes in the delta's flood regime will also impact both the agriculture and aquaculture. Changes in flood arrival time will affect the rice production particularly if the flood arrives much earlier than usual – and thus before current rice harvest season (Figure 19, Figure 18). The extended flood areas may also affect aquaculture and particularly the shrimp ponds located in the coastal areas of the delta (Figure 20).

The above-discussed impacts of climate change on rice production raise naturally serious concerns, as they would directly affect the most important livelihood source in the delta. The diversity of livelihoods in the delta area is relatively low for various reasons (market condition, natural possibilities etc.), and most farmers are therefore highly dependent on farming. This kind of dependency on single livelihood source can be seen to make it more challenging to adapt to the new risks brought by the changing climate.

Selection of rice variety is also highly dependent on market conditions. For example, some rice varieties that would be more resistant to drought and heat are not that well accepted by the market and get therefore lower price, discouraging their cultivation.



**Figure 14.** Simulated changes in future rainfall during the early phases of summer-autumn rice crop season, indicating reduction in practically every part of the delta.

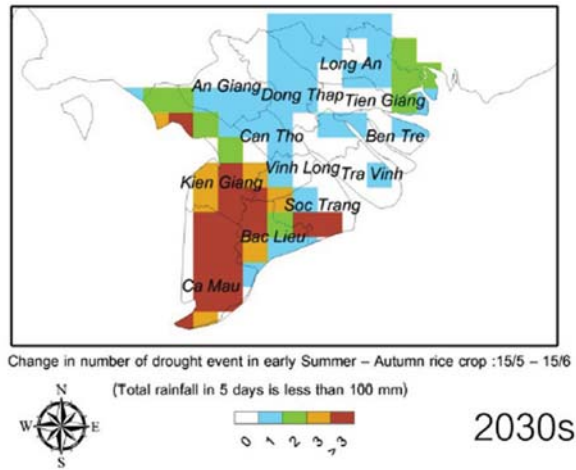


Figure 15. Estimated change in the number of dry-spell events during the early phases of summer–autumn rice crop season in 2030s, indicating increase in dry-spell events in most part of the delta.

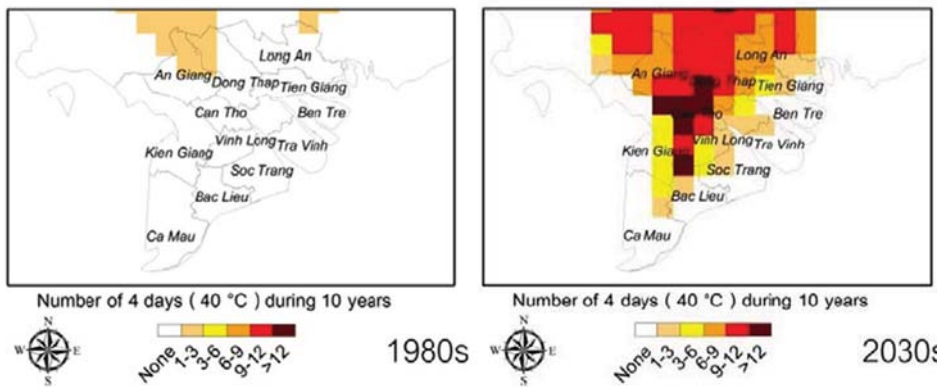


Figure 16. Estimated change in maximum temperature during the early phases of summer–autumn rice crop season by the 2030s, compared to the baseline decade of 1980s (left). The figures indicate clear increase in average maximum temperatures.

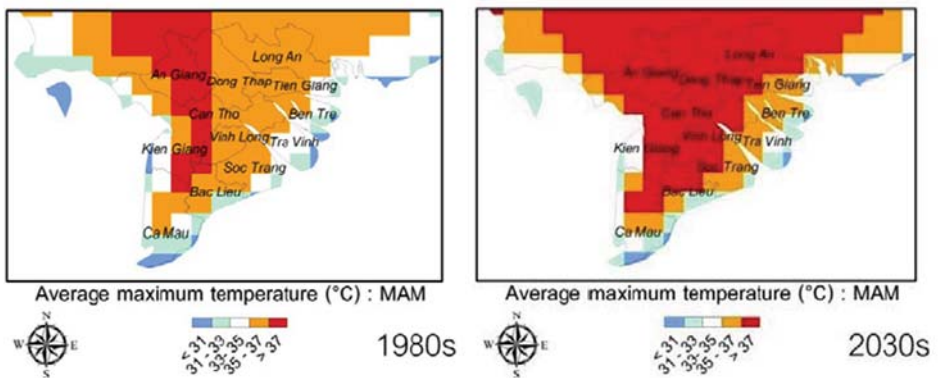


Figure 17. Estimated changes in extreme hot period by 2030s, compared to the baseline decade of 1980s (left).

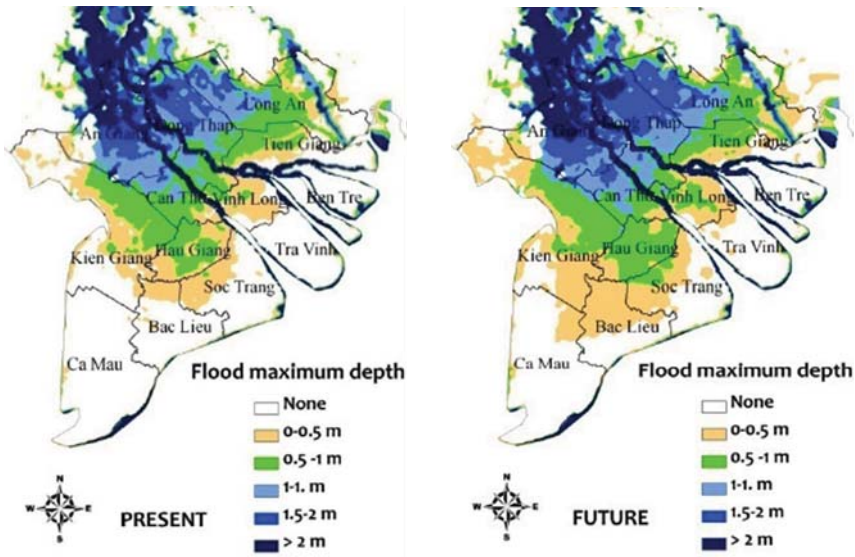


Figure 18. Estimated change in the flooded area in the Mekong Delta in the future (right), compared to the present day (left).

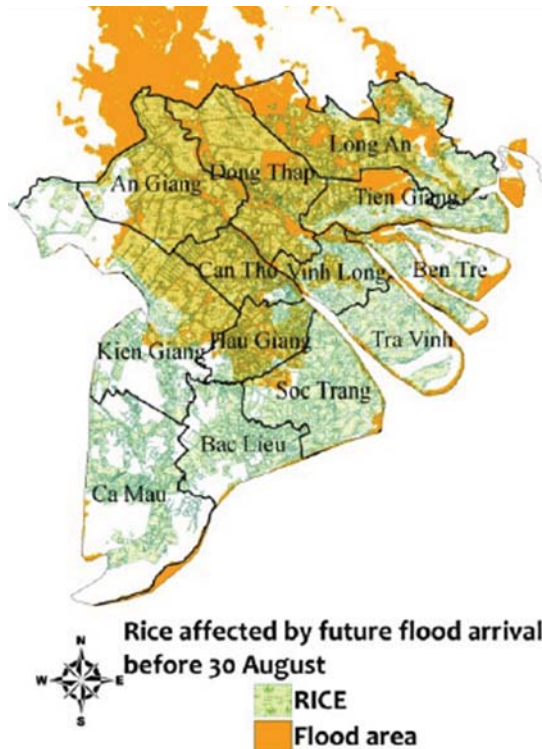


Figure 19. Estimated future occurrence of serious flood ( $\geq 50\text{cm}$ ) that starts before end of August i.e. before the harvest of summer-autumn rice crop.

Changes in flood regime, particularly increase in the water level, naturally also affects the urban areas of the delta, where flooding is largely negative and unwanted phenomena (unlike in the rural areas where normal floods also bring many benefits). To protect the rural areas from flooding, physical

flood protection systems such as dikes may therefore need to be built or further improved. This needs to be done, however, with a particular care and comprehensive planning, as otherwise it brings only partial solution by just shifting the flood risk to other areas that are not that well protected by dikes.

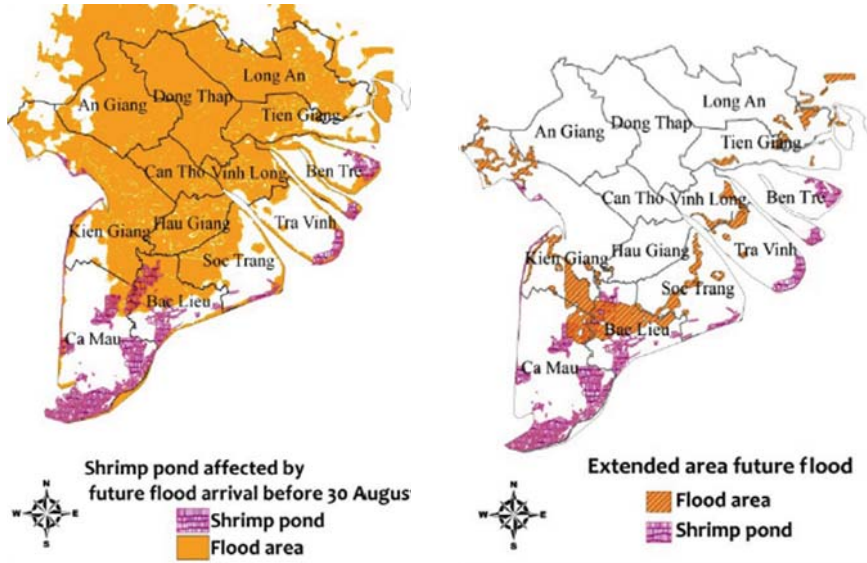


Figure 20. Estimates on extended future flood areas, potentially affecting the shrimp ponds located in the coastal areas of the delta.



## 5 ADAPTATION POLICIES

Both Cambodia and Vietnam already have national policies and strategies related to climate change adaptation. However, as practically all of them are relatively new and are still in the process of being established and elaborated, a very detailed analysis of current adaptation policy setting is practically impossible.

In addition to national adaptation strategies, regional initiatives and programmes for climate change adaptation in the entire Mekong Region exist. An example of more regional initiative is the Climate Change and Adaptation Initiative of the Mekong River Commission (MRC) that was initiated in 2008. The different regional approaches and programmes were discussed in more detail in the Interim Report of this project (TKK & SEA START RC 2008), and will therefore not be discussed in this report.

### 5.1 ADAPTATION POLICIES IN CAMBODIA

Cambodia's role in climate change adaptation is characterized by an interesting dualism: although the people have a relatively high level of adaptation to the natural, highly variable hydrology, the country's economic and institutional capacity to handle unexpected changes remains limited. In terms of official strategies to climate change, however, Cambodia can be regarded to be relatively well placed. Cambodia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and acceded to Kyoto Protocol in 2002. The first step in implementing the Convention was the drafting of Cambodia's Initial National Communication under the UNFCCC in 2002, which describes the country's greenhouse gas inventory and the steps that Cambodia plans to undertake to address climate change.

Cambodian Climate Change Office (CCCO) under the Ministry of Environment was established in June 2003. The CCCO is responsible for the implementation of the country's commitments under the UNFCCC through planning and policy formulation, assessment of new technologies for climate change mitigation and

adaptation, and capacity building and awareness raising on the climate change-related issues (Ponlok 2004).

The main programme for climate change adaptation in Cambodia is the National Adaptation Program of Action to Climate Change (NAPA), published in 2006. Currently the Ministry of Environment and CCCO are also in the process of preparing a report on Vulnerability and Adaptation Assessment to Climate Change in Cambodia as part of its Second National Communication. The objectives of the Cambodian NAPA are (Ministry of Environment 2006):

- 1) understand the main characteristics of climate hazards in Cambodia (flood, drought, windstorm, high tide, salt water intrusion and malaria);
- 2) understand coping mechanisms to climate hazards and climate change at the grassroots level;
- 3) understand existing programmes and institutional arrangements for addressing climate hazards and climate change; and
- 4) identify and prioritise adaptation activities to climate hazards and climate change

The national priorities sectors for climate change adaptation in Cambodia are agriculture, forestry, human health, and the coastal zone. So far the focus has been mostly on post-disaster assistance, but currently more emphasis is being put on prevention methods while also trying to expand the post-disaster assistance to a larger share of the population.

The water resources sector is included in the national priorities mainly through the linkages with agriculture and food security, with majority of the projects being related to building infrastructure, such as irrigation systems, culverts and dikes. Notable is that none of the NAPA reports puts emphasis on fisheries, despite their remarkable social and economic importance and clear vulnerability to environmental changes.

## 5.2 ADAPTATION POLICIES IN VIETNAM

Vietnam has been considered as one of the world's five most vulnerable countries to climate change impacts because of its long low lying coastline and exposure to typhoons, storms, heavy and variable rainfall (MONRE et al. 2008). Policies and strategies to assess the climate change impacts and to respond to them are therefore currently high in the government's agenda. The Ministry of Natural Resources and Environment (MONRE) has the main role in this, as it is responsible for the Vietnamese participation in the UN Framework Convention on Climate Change and the Kyoto Protocol and also the lead agency in new National Target Program to Respond to Climate Change.

Vietnam ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and The Kyoto Protocol in 2002. Similarly to Cambodia, the first actions related to climate change focused on inventories and the reduction of green house gas emissions, and not that much on climate change adaptation. For example the Initial National Communication (INC) to the UNFCCC explored climate change impacts and necessary adaptation measures in a preliminary and qualitative way only.

However, climate change adaptation measures have been included in a number of recent laws and strategies, such as the National Strategy for Environmental Protection of 2005 (Chaudhry & Ruyschaert 2007). Other policy documents for climate change adaptation include the "National Strategy for Environmental Protection until 2010 and vision towards 2020" that was approved on December 2003, and the "National strategy for Natural Disaster Prevention, Response and Mitigation to 2020" that was approved on November 2007. The Socio-Economic Development Plan for 2006-2010 and Vietnam Agenda 21 also provide a policy context for climate change adaptation (MONRE et al. 2008).

In December 2007 the Prime Minister issued a resolution that called for the Ministry of Natural Resources and Environment (MONRE) to be the lead agency in formulation of a National Target Program to Respond to Climate Change. The

overall objective of the program is to enhance Vietnam's capacity and efficiency to response to climate change (MONRE et al. 2008).

According to MONRE et al. (2008), the National Target Program to Respond to Climate Change (NTP-RCC) is based on following main philosophy:

- Responding to Climate Change must base on sustainable development, interaction among sectors/inter-sectors, regions/inter-regions, gender equality and poverty alleviation;
- Activities to cope with climate change should be done with the consideration of the main vulnerable and counting for both immediate impacts and hidden risks in the long run;
- Responding to climate change is the responsibility of the whole society, all authority levels, sectors, various organisations, communities and of every single citizen.
- Responding to climate change is of national, regional and global importance.
- Responding to climate change in Vietnam is primarily related to adaptation however mitigation will be approached under the "common and differentiated responsibilities" approach and provided the developed world support with sufficient capital and technology transfer.

## 5.3 RECOMMENDATIONS ON ADAPTATION POLICIES

The increasing number of initiatives for climate change adaptation show that adaptation is emerging as new, important theme in both Cambodia and Vietnam as well as more regionally in the Mekong Region. This emergence has been supported by the escalating amount of financial and technical resources available by different donors and development banks for climate change adaptation. At the same time, however, the actions on climate change adaptation remain rather scattered and sectoral, and suffer from the lack of coordination and cooperation between different actors. Also the understanding of the broader context related

to climate change adaptation seems to be limited, and adaptation initiatives are still too often carried out in isolation.

We see that this broader context needs to be taken into account in adaptation policies in two different ways. First of all, the other ‘change factors’ impacting water cycle –through which most of climate change impacts are being felt– needs to be better incorporated in both the studies and policies looking at climate change impacts and climate change adaptation. In the current context of the Mekong River Basin, the most important such change factor is the planned hydropower development in the Mekong upstream that is going to cause major changes in the water resources of both the Tonle Sap and the Mekong Delta. In addition, the cumulative impacts of local developments –such as irrigation and other water control structures– to water flows need to be studied as well. Ironically, while many of such structures are likely to be constructed to enhancing the adaptation capacity to the estimated climatic and flow changes, they may actually just shift the risk of such changes to other areas (Lebel 2007).

Secondly –as has been highlighted also by our analyses–, social, economic, institutional and political issues are in many ways at least as important when considering climate change adaptation. Consequently, adaptation to the impacts of climate change should be seen as an integral part of broader development policy. This is particularly so due to

long time perspective – usually several decades – required by climate change adaptation<sup>8</sup>. However, as can be very clearly seen from the institutional arrangements related to climate change adaptation both at national and regional levels<sup>9</sup>, climate change – including adaptation to its impacts – is still considered first and foremost as an environmental issue.

Related to this, the understanding of the kind of time perspective needed for climate change adaptation is often missing, and the differences between shorter and longer term impacts and actions seems always not to be clear. Indeed, it sometimes even seems that the immediate response needed for climate change mitigation is confused with much longer term view needed when looking at climate change impacts and adaptation to them.

Finally, the strategies and actions related to climate change adaptation seems still to be largely based on sectoral approaches, with each sector (such as agriculture, fisheries, industry, urban areas etc.) having their own specific means to enhance adaptation capacity. While this is clearly important for continuity and for connecting climate change adaptation activities with other, broader initiatives, it also leads easily to overlaps and lack of communication between the sectors. To avoid this, we see an area-based approach – instead of a sectoral one – for climate change adaptation as one plausible solution. This is discussed more in the next, concluding chapter.

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<sup>8</sup> One needs only to think back 30 years – rather short time in terms of climate change adaptation – and consider how fundamentally different both the Tonle Sap area and the Mekong Delta – and indeed Cambodia and Vietnam – were in terms of social, economic and institutional issues.

<sup>9</sup> This environmental orientation towards climate change is visible also in the institutional arrangement both in Cambodia (where the Climate Change Office is located under the Ministry of Environment) and in Vietnam (where the Ministry of Natural Resources and Environment is the responsible government agency for climate change-related issues, including the responses to climate change impacts). Same also applies at the regional level, as e.g. regional Climate Change Adaptation Initiative under the Mekong River Commission is lead by the MRC Environment Programme.





## 6 CONCLUSIONS AND RECOMMENDATIONS

Current climate change estimates indicate that major environmental changes are likely to occur due to climate change in practically every part of the world, with majority of these changes being felt through modification of hydrological cycle as e.g. floods, droughts and storms. Mekong Region is naturally not any different and our two case study areas –the Tonle Sap area and the Mekong Delta– represent in many ways two particularly vulnerable areas to climate change impacts.

In the Tonle Sap –as well as in the Cambodian floodplains overall– the climate change impacts are largely to be felt through changes in the flows of the Mekong River, and the impacts are estimated to change the area’s unique flood pulse system, potentially altering the high aquatic productivity of the lake-floodplain system. In the Mekong Delta of Vietnam, the impacts are also going to be felt through changes within the river basin, but also through estimated increase in seawater level.

In both of these areas the estimated climate change impacts are thus essentially being felt through regional rather than local changes, and they are going to be felt on top of other change factors within the Mekong River system. The on-going hydropower development is clearly the most important such change factor. Thus, the climate change impacts and adaptation to them in both the Tonle Sap and the Mekong Delta is very much a regional issue, and national adaptation strategies need therefore to consider also regional perspectives.

Climate change adaptation has quickly become one of the focal points of current development discussion both globally and within the Mekong Region. There are naturally very good reasons for this, as the negative impacts of climate change are likely to magnify the challenges that the affected populations are already facing, particularly when looking things in more long term. In addition, these impacts are likely to result in increasing inequity, as the impacts are to be felt most strongly by the groups that already now among the poorest and the most vulnerable – this seems to be the case also in both Cambodia and Vietnam (Nuorteva 2009, Chaudhry, P. & Ruysschaert 2007).

At the same time the changing climate may also bring opportunities, many of which are not yet fully understood or recognised. Consequently, climate change adaptation is indeed an important issue to address at local, national as well as regional level. The following chapters provide some general conclusions and recommendations for climate change adaptation in the Lower Mekong Basin.

### 6.1 CLIMATE CHANGE SCENARIOS: WARMER & WETTER

The results from the two climate change scenarios indicate that the Mekong Region will in the future become slightly warmer, but duration of warm periods will extend much longer than currently and cover much wider coverage. The rainfall estimates show fluctuation in the first half of this century, but demonstrate then increasing trend during the latter half of the century. This increasing trend results from increasing rainfall intensity, as the length of the rainy season is estimated to be more or less the same than presently.

In addition, the impacts from sea level rise, which is caused by changes in wind speed and wind direction of the monsoon system (especially the northeast monsoon) together with the effect of global warming on the water expansion in the ocean, will be significant particularly in the Mekong Delta. It is worth noting that the effect of sea level rise from ice sheet melting was not taken into consideration as it is considered largely inconclusive (IPCC 2007). However, it is believed that the melting of polar ice sheet will affect the sea level rise and would add to already estimated hydrodynamic changes in the Mekong Delta floodplain system, together with direct impacts on the coastal zones.

### 6.2 HYDROLOGICAL AND HYDRODYNAMIC CHANGES: CHANGES IN FLOODING

The analysis of hydrological impacts of climate change indicate that out of the two climate change-related impacts, the changed basin hydrology has

much more significant impacts on the Tonle Sap flood pulse than the projected sea level rise in the South China Sea. On the other hand, the impacts caused by sea level rise are very consistent throughout the simulated period of 40 years, increasing in magnitude decade by decade, whereas the impacts of changed basin hydrology are more varied in both magnitude and direction of change. In addition, the sea level rise has in the delta much more significant impact on the future water level and flooding characteristics than the changed basin hydrology. The impacts of sea level rise are most significant during relatively lower water levels, such as during the dry season and/or the driest water years.

A clear majority of the simulated climate scenarios produced similar results: future flood pulse in the Tonle Sap and the Cambodian floodplains is likely to be wetter with higher water levels and more extensive flooded area as well as longer flood duration. Notable is that also the modelling results estimate that average water level in the Tonle Sap during the dry season i.e February–July is likely to increase<sup>10</sup>. Table 2 summarises the likely impacts on each flood pulse characteristic and other hydrological variables, based on the average of all simulated climate scenarios. Earlier flood

start date, higher annual average water level and increasing flood duration were simulated for 83–89 % of the scenarios.

The modelling results indicate that particularly the average and driest water years are likely to be wetter in the future compared to the baseline period of 1995–2004. The wettest water years show less clear trend, as the average and maximum water levels are estimated to be lower than in the baseline period during the 2010s and 2020s, but equal to or higher than baseline in the 2030s and 2040s.

### 6.2.1 Cumulative impact assessment and the importance of timescales

Climate change is naturally not the only ‘change factor’ that is having an impact on the Mekong flows. In the Mekong River Basin, increasing number of water infrastructure development is likely to be seen within next decades. The current impact assessments indicate that particularly the planned construction of the large hydropower dams in the Mekong upstream is likely to cause significant impacts in the Lower Mekong floodplains, both in terms of water quantity and quality (see e.g. MRCS/WUP-FIN 2007, Keskinen 2008, Kummu & Sarkkula 2008, Kummu et al. 2008).

**Table 2.** Trend of climate change impacts on the characteristics of the Tonle Sap flood pulse and other hydrological variables as average of all simulated climate scenarios.

HYDROLOGICAL VARIABLE	CHANGE	DESCRIPTION
Average water level (Feb–Jul)	↑	Very likely increases
Average water level (Aug–Jan)	↑	Likely increases
Annual cumulative flooded area	↑	Very likely increases
Maximum water level	↑	Likely increases
Maximum flooded area	↑	Likely increases
Flood start date	←	Very likely occurs earlier
Flood peak date	→ / ←	Occurs possibly later in the average years and earlier in the driest years
Flood end date	→	Likely occurs later
Flood duration	↑	Likely increases

<sup>10</sup> However, there seems to be some uncertainty for describing this particular hydrological variable and the results need therefore to be considered with specific care.

Consequently, the hydropower development can be seen as the most important additional change factor to be considered when assessing the potential impacts of climate change. However, several other changes at both regional and local levels are impacting the Mekong’s water resources as well, and to fully understand the combined impacts of these different changes, a cumulative impact assessment incorporating the different changes at different timescales should be carried out.

estimated to be opposite to each other. The clear exception to this is the dry season water level that is estimated to increase due to both hydropower development and climate change. Given the radical negative impacts that this would potentially have for the floodplain ecosystems (see e.g. Kumm & Sarkkula 2008, Keskinen et al. 2007), this combined impact of increased dry season water level poses a serious concern particularly for the Tonle Sap and its high fish productivity.

When comparing the impacts of these two potentially dominant changes – hydropower development and climate change –, it is interesting to notice that their estimated impacts to most of the hydrological variables presented in Table 2 are

In addition, the impacts due to different change factors are likely to occur at considerably different timescales, and they cannot therefore considered to be ‘balancing off’ each other. While the most remarkable changes in climate-related variables

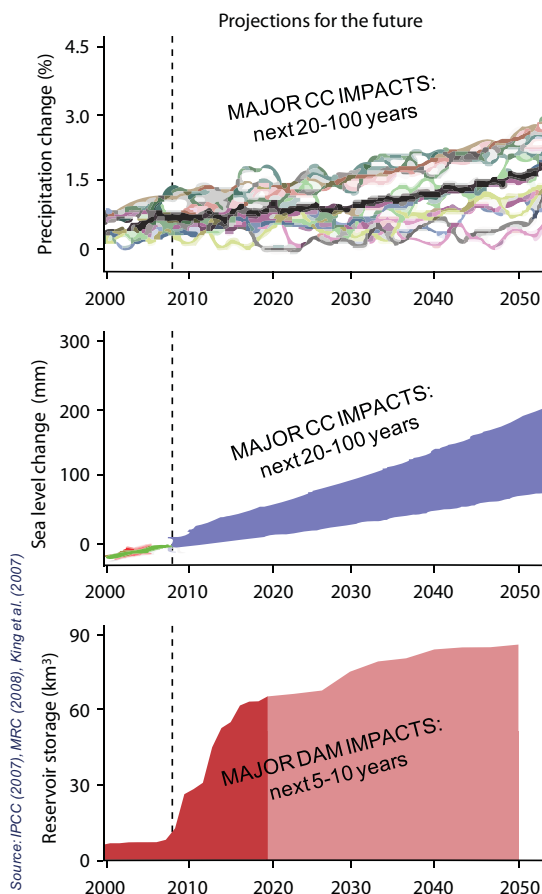


Figure 21. Diagrams showing the future projections for two climate-related variables, precipitation and sea level change (two uppermost diagram), compared to the change in planned reservoir storage in the Mekong Basin (data modified from IPCC 2007, MRC 2008 & King et al. 2007).

such as precipitation and sea level rise are estimated to occur only in the time span of several decades, the changes caused by hydropower development e.g. in terms of increasing reservoir capacity, are going to be felt with much shorter timescale, possibly already over next 5-15 years. This is clearly illustrated in Figure 21 that shows the slowly increasing trend in climatic variables over the next decades, and compares those to the projected changes in the storage capacity of planned hydropower reservoirs.

When considering the combined impacts of different change factors, it is thus clear that the assessment of potential impacts of climate change should not be carried out separately, but together with other potential change factors, making use of cumulative impact assessment approaches. To really capture the potential cumulative impacts, the impacts of the different changes should also be considered both in shorter and longer term.

### **6.3 LIVELIHOODS & LOCAL ADAPTATION STRATEGIES: INCREASING VULNERABILITY**

The findings from the analysis of livelihoods and adaptation capacity in the Tonle Sap indicate that while people are well adapted to remarkable seasonal variation of the Tonle Sap's waters, their adaptation capacity towards unusual water regimes –such as extraordinary high floods or sudden storms– is relatively limited. Particularly limited is the adaptation capacity of the poorest groups, as their already low living standards and asset-base intensifies their vulnerability to challenges to their livelihoods. The situation seems to be similar in all study villages i.e. in the floating villages in the lake as well as in the agricultural villages further up in the floodplains.

One efficient strategy for adapting to the impacts of environmental changes (including but not limited to climate change) is to increase the general standard of living and the prerequisites to maintain a productive livelihood. Equally important is to support local capacities and institutions to cope with both sudden shocks as well as with more long-term stresses and changes.

The results from the field studies in the Tonle Sap as well as from the stakeholder consultation in the Mekong Delta indicate that any efforts to enhance local adaptation capacity should build on existing livelihoods and strengths at the local level as well as lessons learnt from the unexceptional events of the past. The informants both in the Tonle Sap and the Delta had several ideas about the sort of activities through which they could improve their future livelihoods and to enhance thus their resilience and adaptation capacity. Supporting and nurturing these ideas can thus be seen as one of the keys for enhancing the adaptation capacities at the local level.

### **6.4 OVERALL CONCLUSIONS & RECOMMENDATIONS**

In addition to more specific conclusions and recommendations related to different research components, we have recognised six overall recommendations that we consider particularly important in terms of climate change adaptation in the Mekong Region.

#### **1) Water cycle critical for climate change adaptation**

As much as climate change mitigation is about energy, climate change adaptation is about water. This is so because majority of the climate change impacts, such as floods, droughts and extreme weather conditions, are essentially due to the changes in hydrological cycle (see e.g. Keskinen 2007; IPCC 2007). Climate change's impacts are thus primarily mediated to environment and to the society by alterations of hydrological cycle (Falkenmark 2007).

It is also important to note that several remaining uncertainties related to climate change are closely connected water. Many of the uncertainties in the global climate models, for example, are linked to hydrological cycle, such as the uncertainties related to atmospheric feedback, cloud systems and ocean processes (IPCC 2007). This highlights further the need for better understanding of climate-water interactions as well as the central role that water cycle has in mediating the impacts of climate change.

## 2) Climate change is not the only change around

Our research indicates clearly that while climate change is estimated to bring significant environmental changes to the study areas and the entire Lower Mekong Basin, there are also several other factors that are likely induce changes in the area. In terms of changes in water resources and environment, most important such ‘change factor’ is the already on-going hydropower development in the Mekong upstream.

It is therefore important that any activities related to climate change adaptation are not carried out in isolation, but are linked to other change factors expected to occur in the area. The studies should thus not be focusing on climate change only, but rather on adaptation to overall environmental changes likely to occur in shorter and longer term due to different factors. Climate change and its impacts thus form an important cross-cutting issue – or as a risk multiplier – that should be taken into account when looking at the variety of changes likely to occur at different temporal and spatial scales.

In terms of actual assessment of climate change impacts, there is thus a need for integrated assessment of different changes impacting water resources, instead of separate assessments focusing on climate change, dams etc. Consequently, any assessment of climate change impacts should build on Cumulative Impact Assessments (CIA) that look similarly – and cumulatively – at different change factors and their estimated impacts.

## 3) Importance of timescales

Linked to above, it is critical to bear in mind the long-term perspective that is required in climate change adaptation (which should also not be mixed with the much more immediate responses needed for climate change mitigation). All climate change adaptation activities should therefore build on both shorter- and longer-term view as well as clear understanding of the changes – and their causes – at different time scales.

Why this is so important? Because while most climate change impact estimates look at far into the future (usually up to 50-100 years), other changes in water resources – in the Mekong particularly

large-scale hydropower dams – are to be felt within much shorter time scale i.e. within few years and decades. The uncertainties included in these estimates are also usually less than in longer-term climate change estimates.

Besides to the environmental changes, similarly rapid are other changes – social, economic, political and institutional – likely to impact the actual adaptation capacity. Due to long time perspective needed in climate change adaptation, these kinds of changes are in most cases likely to be the main bottlenecks – or solutions – for sustainable adaptation

## 4) Remembering the broader context

Adaptation capacity builds not only on environmental resilience, but also – and predominantly – on people and institutions. Thus, there is a need to understand that in addition to changes affecting directly water resources and environment, there are other changes that have a remarkable effect on the way the adaptation capacity is actually being developed and enhanced.

These change factors are varied, but they include first and foremost social, economic, political and institutional changes that are taking place at different levels. It is thus important to realise the close links that climate change adaptation has with more general development strategies, and not to consider adaptation as a new, separate entity.

Indeed, we see that climate change adaptation should be seen as an integral part of broader development policy, and not merely as an environmental issue. Consequently, as development policy is being planned, long-term vision for the area in question should be developed and assessment on impact of climate change conducted based on the desired outcome of the development policy.

At the same time it is important to note that both environment and socio-political context are never static, but are continuously evolving. Consequently, we feel that generic ‘simple solutions’ cannot really be established for climate change adaptation, as a solution that may seem feasible in today’s circumstances may be out-of-date in tomorrow’s setting. Instead, the entire climate

change adaptation should be seen as an extremely dynamic process that needs to be both flexible and adaptive, so that it can respond and adjust to changing conditions and situations.

### 5) Building on existing strategies to enhance adaptation capacity

The findings from our research indicate that the most feasible ways to build adaptation capacity at the local level are essentially the same than those needed e.g. in poverty reduction and sustainable development. Climate change adaptation doesn't therefore necessarily require doing new things, but rather doing old things even better than before.

Enhancing climate change adaptation should thus be based on the experiences from these initiatives, and support them further to respond also the emerging impacts from climate change. In many cases the most straightforward way to increase the resilience and adaptation capacity is support local livelihoods and enhance the living conditions of local people, and the poorest in particular. There is also plenty to learn from the past experiences from unusual phenomena and circumstances (such as higher than normal floods) in terms of recognising both successful and not-so-successful adaptation mechanics as well as possible knowledge and action gaps.

### 6) Area-based approach for adaptation

The current search for so-called 'simple solutions' on climate change adaptation also forgets that situations and contexts differ, and a sound solution in one context may actually turn to be a complete failure in another, as changing climate produces different impacts at different locations. Moreover, adaptive capacity -which is always context dependent- will

make each area vulnerable to climate change impacts differently. Consequently, climate change adaptation should consider holistically the specific aspects and sectors of each area.

To reduce the overlaps and lack of communication between the different climate-related sectors, we see an area-based –instead of sectoral– approach for climate change adaptation as plausible solution. A society in any particular area consists of various sectors that have several interconnections between them. These sectors are threatened differently by climate risk and they also respond to the impacts differently. In addition, their responses may affect risk condition and/or choices of adaptation measure of other sectors. Assessment of future climate risks and related adaptation policies should therefore be based on a holistic approach that considers the specific context of each area.

We see that potential benefits of area-based approach include the following issues: 1) Bringing practical, context-specific challenges and opportunities better into the discussion, 2) Improving the understanding of broader context, including institutional, social and economic issues, and 3) Encouraging different sectors to work better together.

Moreover, as climate change adaptation requires long time perspective, future changes in socio-political conditions need also to be included in the assessment of future climate risk. In this context, adaptation policy should be considered as a strategy that provides a general, flexible framework for future actions. In other words, climate change adaptation can be seen as an overall framework for plausible adaptation, while the actual actions for adaptation need then to be planned at local level, taking into consideration the local contexts of each and every area.





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## ANNEX A: PRECIS REGIONAL CLIMATE MODEL AND ITS VALIDATION

The climate model used in this project for downscaling the climate scenarios to the Mekong Region is called PRECIS. It is a regional climate model that was developed by Hadley Centre for Climate Prediction and Research. It can be used as downscaling tool that adds fine scale (high resolution) information to the large-scale projections of a global general circulation model (GCM). While GCMs are typically run with horizontal scales of 300km, regional models can resolve features down to 50km or less. This kind of downscaling enables more accurate representation of different surface features, such as complex mountain topographies and coastlines, and also allows small islands and peninsulas to be represented more realistically. PRECIS can be run on a PC with a simple user interface, so that experiments can easily be set up over different region (Jones et al. 2004).

The results from PRECIS regional climate model were verified with data from observation stations. The period of 1980s was selected as baseline for verification. The comparison shows that the temperature is overestimated in many areas (Figure 22).

The difference between the simulated and observed data was used to rescale the model output. Values of

the different between simulated and observed data at each station grid were interpolated in order to get the factor for rescaling each climate grid throughout the domain. The maximum temperature of each grid was adjusted and the rescaled result is more realistic when compare to observed data, which falls into the range of  $\pm 1^{\circ}\text{C}$ . This rescale factor pattern was used to rescale future maximum temperature throughout the simulation period (Figure 23).

The regional climate model also overestimates minimum temperature as illustrated in Figure 24.

The rescale process of minimum temperature is based on the rescaled result of maximum temperature. The different between maximum and minimum temperature of each grid in each day from regional climate model output was applied to the rescaled result of maximum temperature. The rescaled result of minimum temperature is slightly underestimated in some area, especially in the in-land area of the simulation domain, and over estimated in some areas, which is mostly in the area near the coastline (Figure 25).

PRECIS regional climate model also underestimated total precipitation almost throughout the simulated

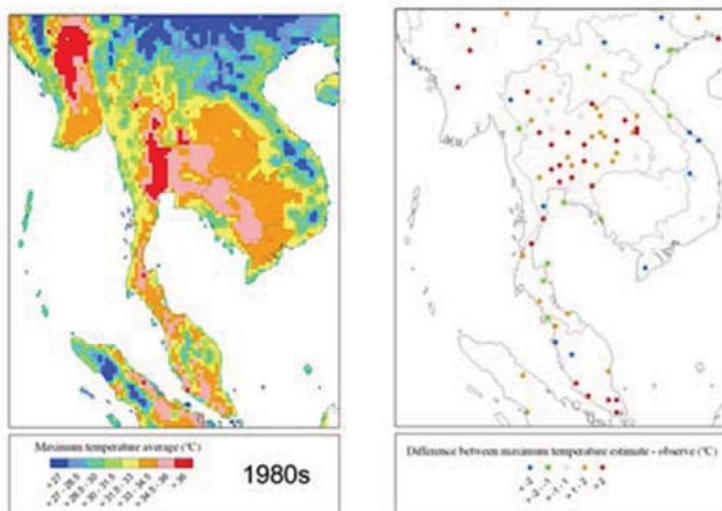


Figure 22. Comparison of average daily maximum temperature between PRECIS model result and observed data.

domain (Figure 26), probably due to the fact that the Global Circulation Model (GCM) does not well capture the effect of tropical storm that cause rainfall in the region. The rescale process using the different value between the simulation and observation was also applied.

The annual precipitation of each grid was adjusted and the rescaled result is more realistic when compare to observed data, which falls into the range of +/- 50mm per annum. This rescale factor pattern was used to rescale future precipitation throughout the simulation period (Figure 27).

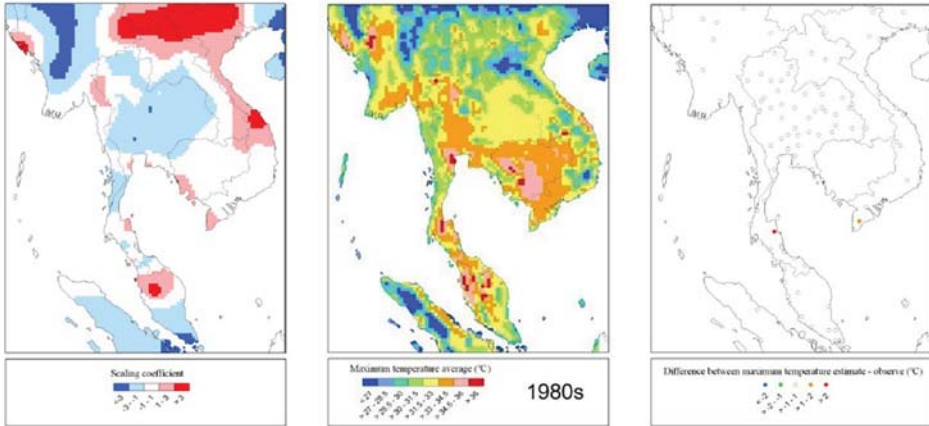


Figure 23. Rescaling factor, result of average maximum temperature after rescaling and comparison between rescaled result and observed data.

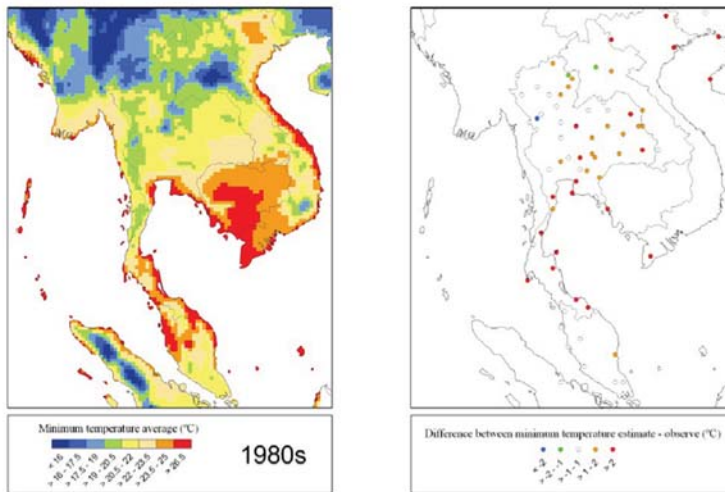


Figure 24. Comparison of average daily minimum temperature between PRECIS model result and observed data.

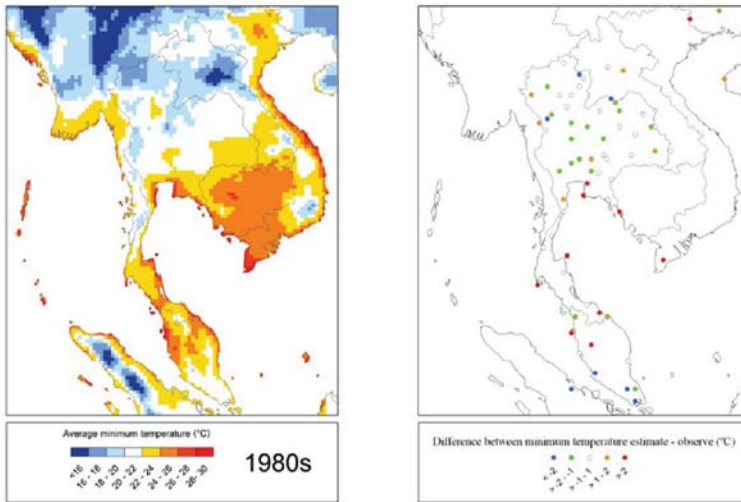


Figure 25. Result of average minimum temperature after rescaling and comparison between rescaled result and observed data.

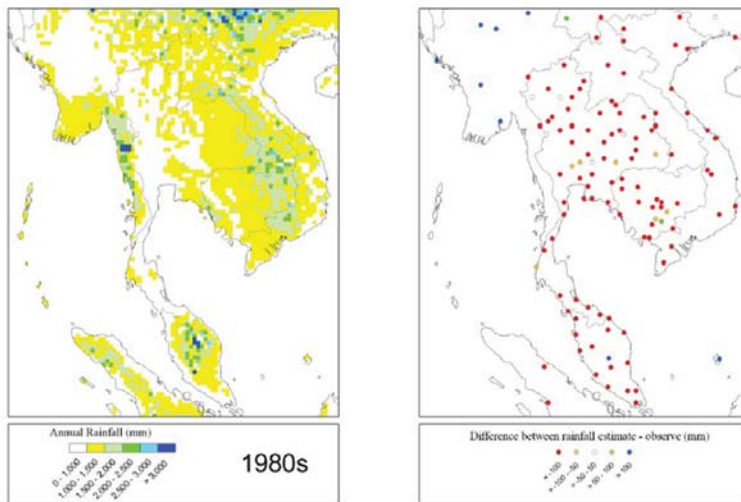


Figure 26. Comparison of average annual precipitation between PRECIS model result and observed data.

### ANNEX B: FUTURE CLIMATE PROJECTIONS UNDER TWO CLIMATE SCENARIOS

This Annex provides a summary of results under two climate scenarios i.e. ECHAM4 A2 and ECHAM4 B2. The figures below present the estimated changes in temperature and precipitation under the two scenarios for the Mekong Region.

These predicted changes are then used as foundation for the actual climate change impact analysis in the Mekong Basin, as the basin-wide hydrological model uses the climate scenarios as boundary conditions for precipitation and temperature.

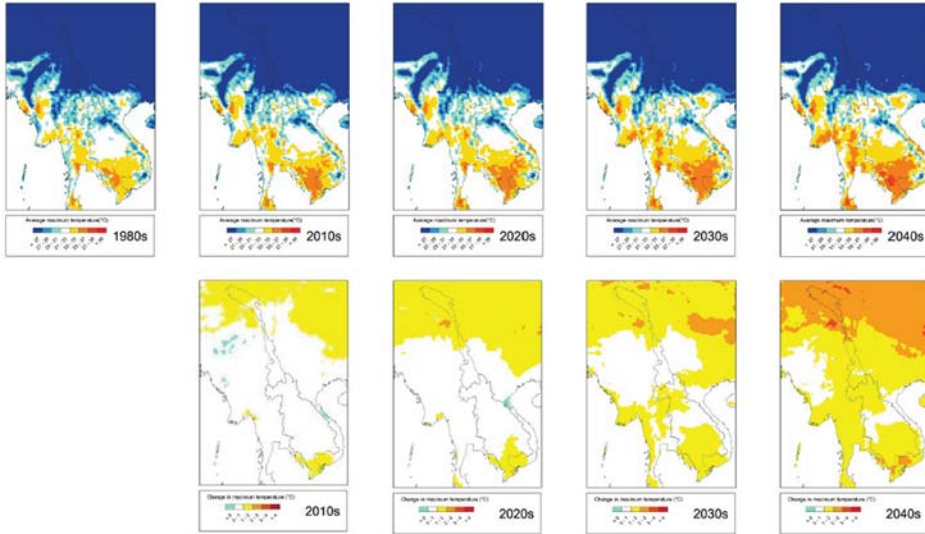


Figure 28. Average daily maximum temperature (top) and future change in maximum temperature compared to the baseline decade of 1980s (bottom) under A2 climate scenario.

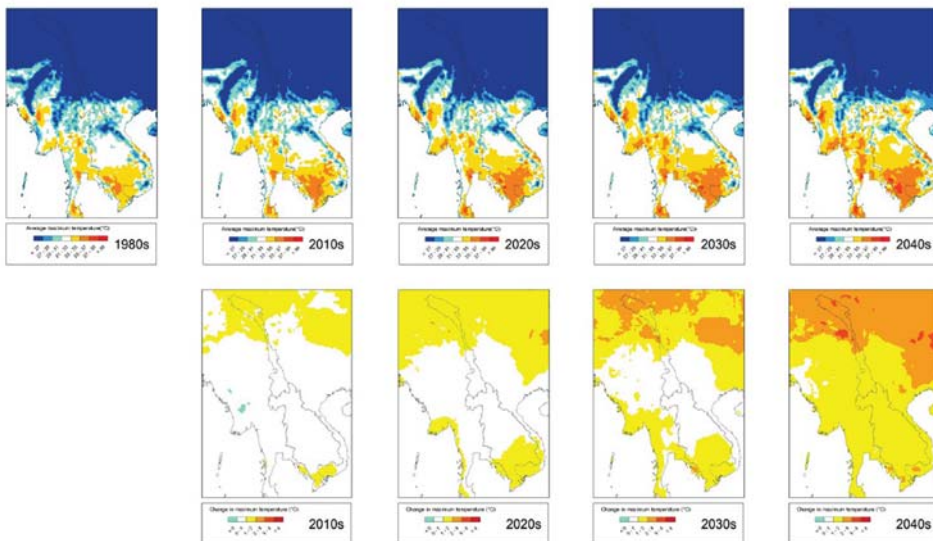


Figure 29. Average daily maximum temperature (top) and future change in maximum temperature compared to the baseline decade of 1980s (bottom) under B2 climate scenario.

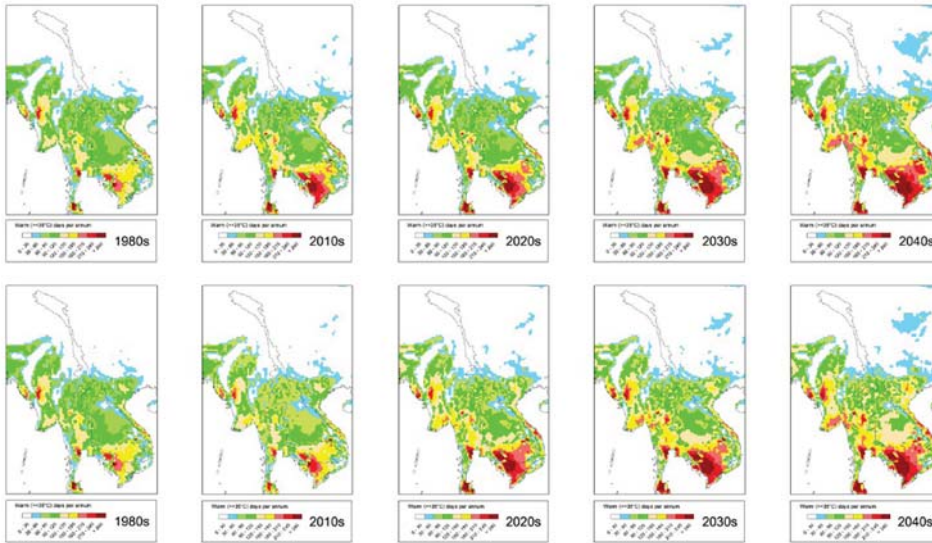


Figure 30. Average number of annual hot days (maximum temperature  $\geq 35^{\circ}\text{C}$ ) under A2 scenario (top) and B2 scenario (bottom).

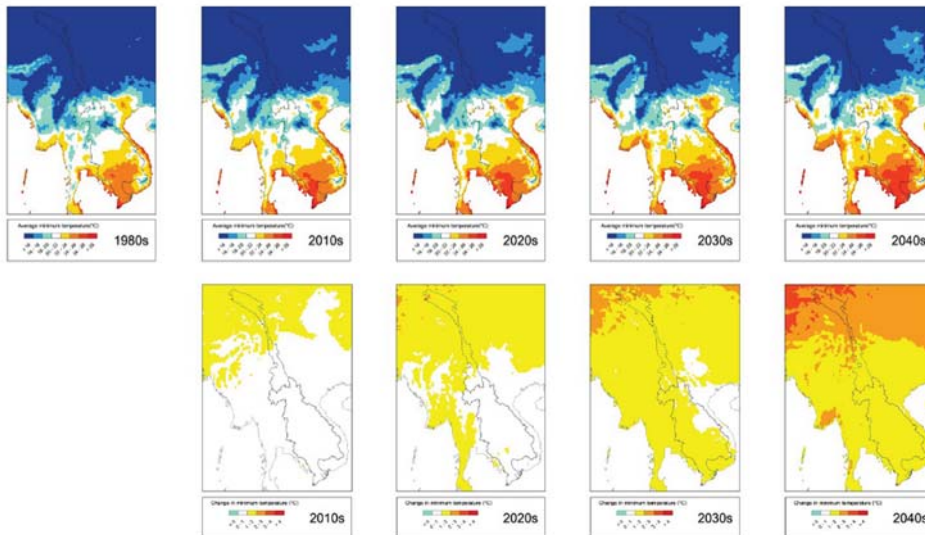


Figure 31. Average daily minimum temperature (top) and future change in minimum temperature compared to the baseline decade of 1980s (bottom) under A2 climate scenario.

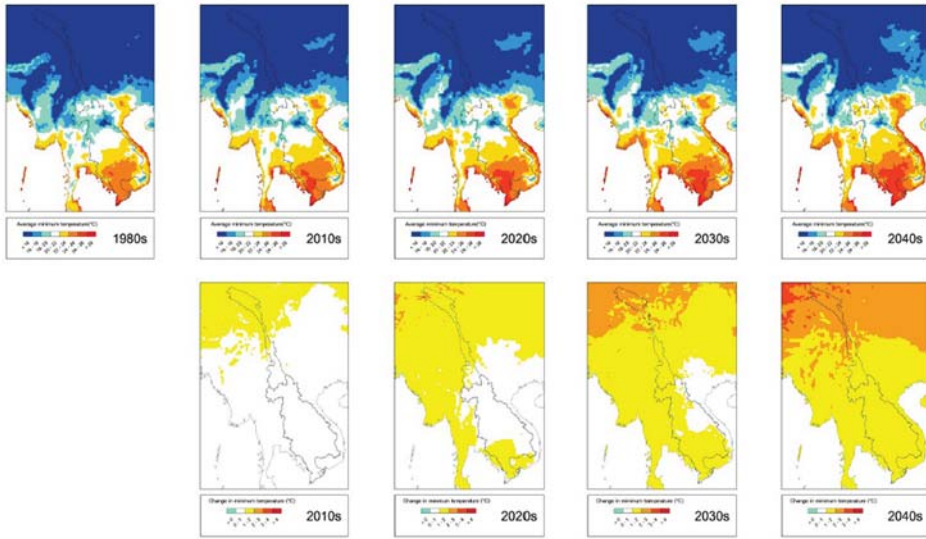


Figure 32. Average daily minimum temperature (top) and future change in minimum temperature compared to the baseline decade of 1980s (bottom) under B2 scenario.

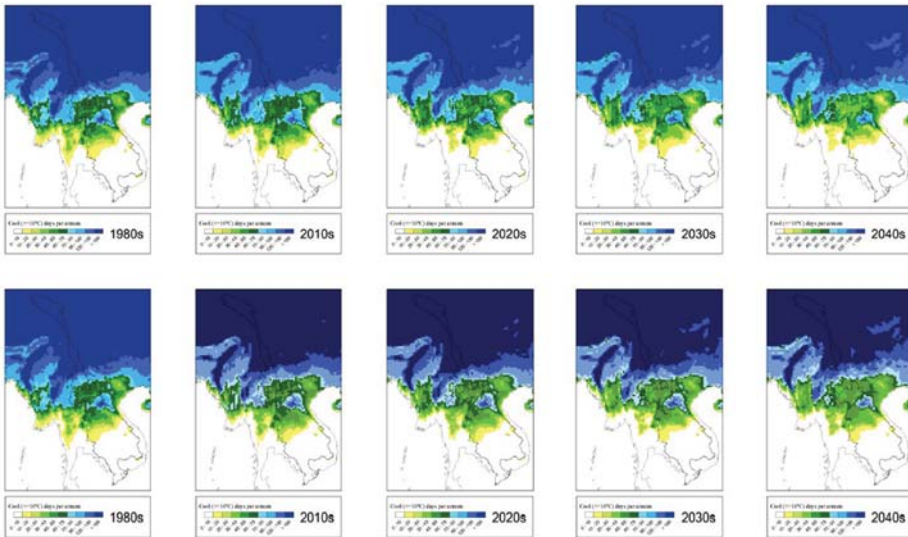


Figure 33. Average number of annual cool days (minimum temperature  $\leq 16^{\circ}\text{C}$ ) under A2 scenario (top) and B2 scenario (bottom).



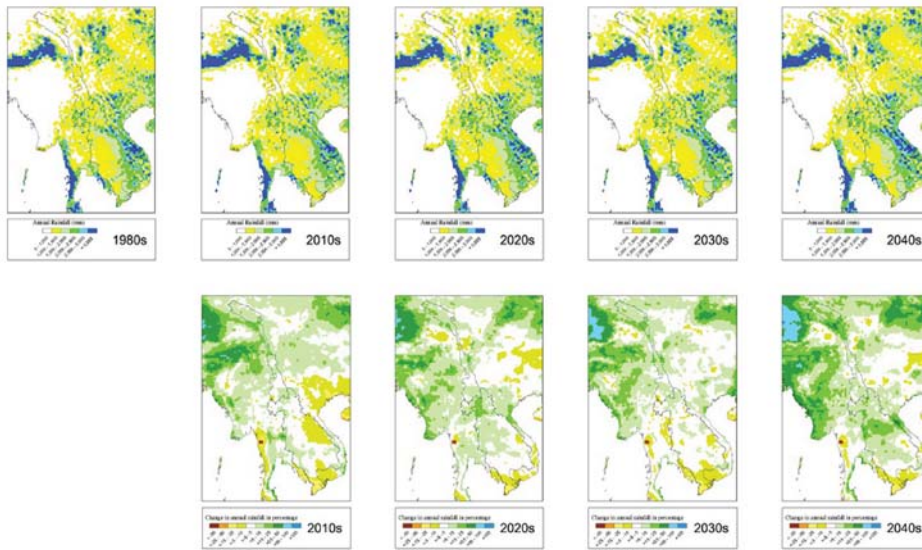


Figure 34. Average annual rainfall i.e. precipitation (top) and future change in the annual rainfall compared to the baseline decade of 1980s (bottom) under A2 climate scenario.

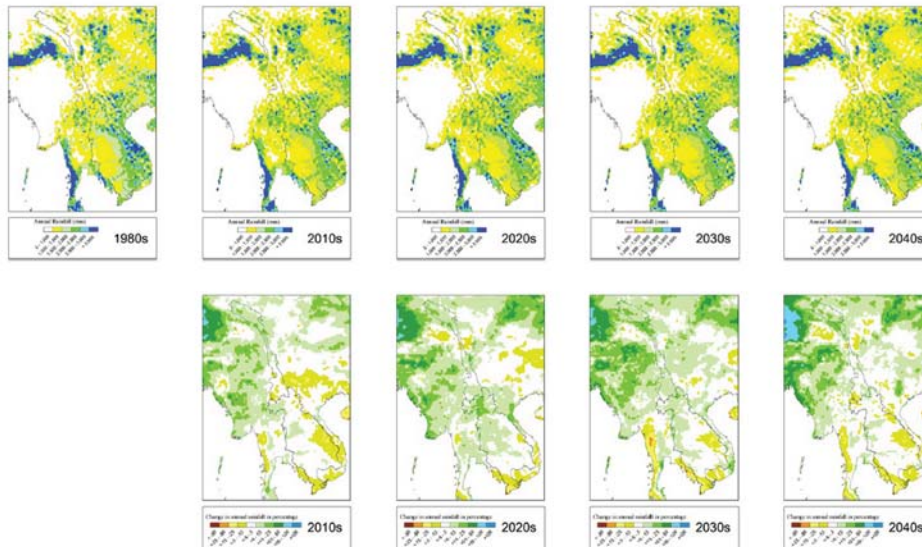


Figure 35. Average annual rainfall i.e. precipitation (top) and future change in the annual rainfall compared to the baseline decade of 1980s (bottom) under B2 climate scenario.

### ANNEX C: FUTURE CLIMATE SCENARIOS FOR THE MEKONG DELTA

Estimated changes in the climate pattern of the Mekong River Delta can be detected from the results of future climate projection. The results show that in the future the region is likely to be warmer with extended summertime. In addition, annual precipitation will be less than currently (Figure 36 – Figure 38).

the uncertainty of long-term climate projections, additional climate scenarios should be developed and used.

It is also worth to note that this climate change projection focuses on long-term changes in temperature and rainfall, and doesn't thus consider extreme weather events such as tropical storms and their impacts in the delta. However, as has been illustrated by the past storm event, tropical storms and their probable increasing intensity is also a major climatic concern for the region.

It is important to note, however, that the results presented in this Annex are based on just single scenario that was used to project long-term climatic changes in the area. In order to better understand

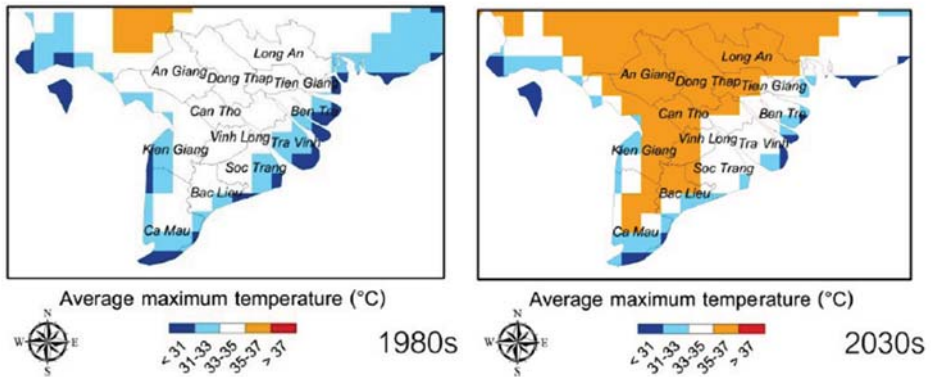


Figure 36. Change in future average maximum temperature in the Mekong Delta.

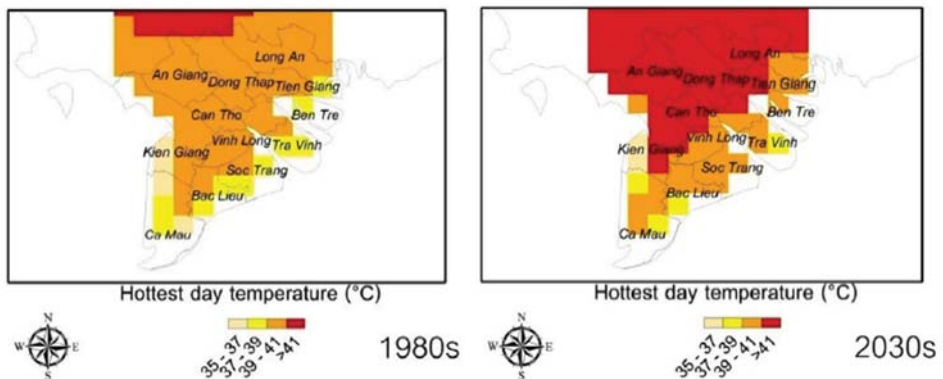


Figure 37. Change in future extreme maximum temperature condition in the Mekong Delta.

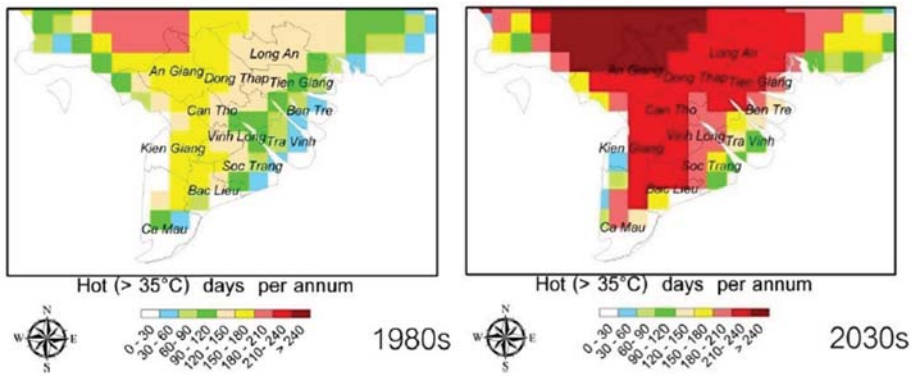


Figure 38. Change in future period of summertime in the Mekong Delta.

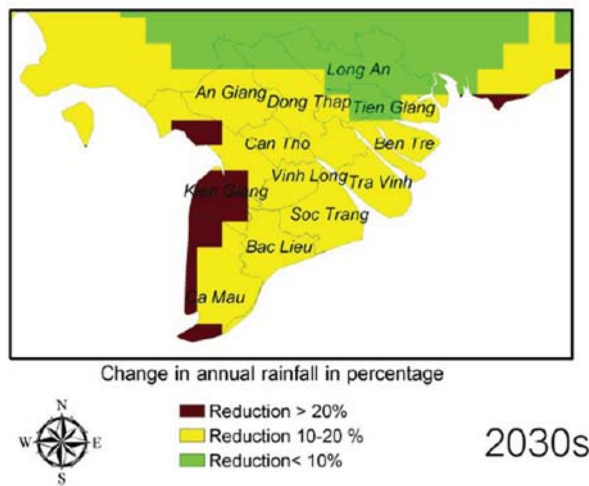


Figure 39. Change in future annual precipitation in the Mekong Delta.

## ANNEX D: BASIN-WIDE HYDROLOGY – VIC MODEL

The simulation on basin-wide hydrological regime under influence of future climate projection was based on the Variable Infiltration Capacity (VIC) hydrological model. VIC is a macro-scale hydrologic model that solves full water and energy balances, originally developed by Xu Liang at the University of Washington (Liang, et al. 1994). It is a semi-distributed grid-based hydrological model that parameterizes the dominant hydro meteorological processes taking place at the land surface - atmosphere interface. A mosaic representation of land surface cover, and sub grid parameterizations for infiltration and the spatial variability of precipitation, account for sub-grid scale heterogeneities in key hydrological processes.

The model uses two soil layers and a vegetation layer with energy and moisture fluxes exchanged between the layers. Vegetation and soil characteristics associated with each grid cell are reflected in sets of vegetation and soil parameters. Parameters for vegetation types are specified in a user defined library of vegetation classes (usually derived from standard, national classification schemes), while their distribution over the gridded land surface area is specified in a vegetation parameter file. Soil characteristics (e.g. sand and clay percents, bulk density) can be represented for a user-defined number of vertical soil layers - usually two or three,

divided into a thin upper layer and a secondary set of layers that extend several meters into the soil column (Lohman, et al. 1998).

Baseline analysis for model validation uses data from climate model during year 1995 to year 2000 to generate discharge at Kratie station in Cambodia and compare the result with the observed river flow data. Result from comparison shows that the simulated flow in the wet season is overestimated, but the flow in dry season is under estimated to almost totally dry.

Model adjustment was performed by adjusting the base flow runoff to contain more water in each grid cell, which in turn will result in reducing peak flow during the wet season. The flow in dry season was adjusted by a constant value, which comes from the observed data through the validation period (1995- 2000), and taken into consideration the monthly flow pattern as well as total annual flow using function in solver to calculate. The result from the adjustment has improved to acceptable level (Figure 41 and Figure 42).

The adjustment process which was used in validation and calibration would then be applied to the adjustment of future flow.

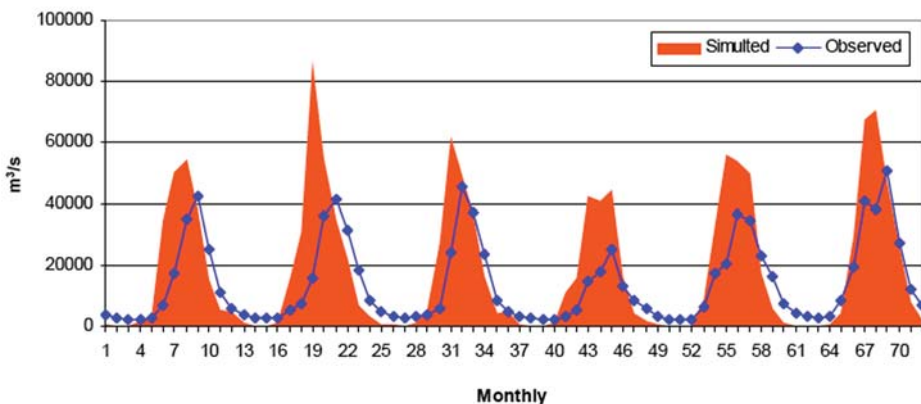


Figure 40. Monthly discharge comparison at Kratie Station – Simulation results vs. Observed.

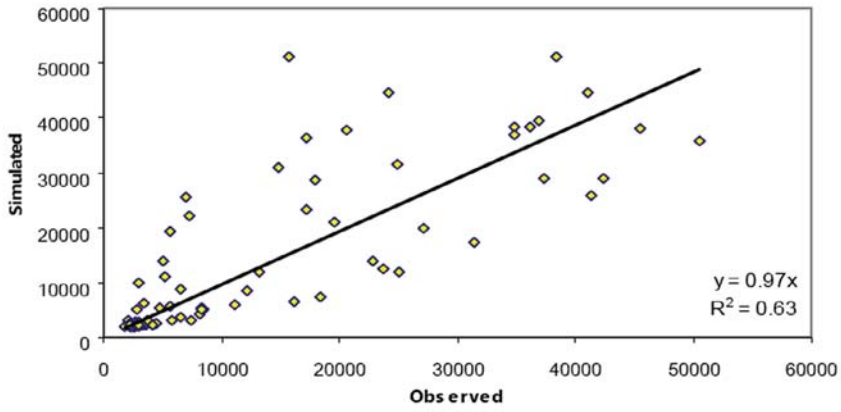


Figure 41. Monthly discharge comparison at Kratie Station – Adjusted simulation results vs. observed.

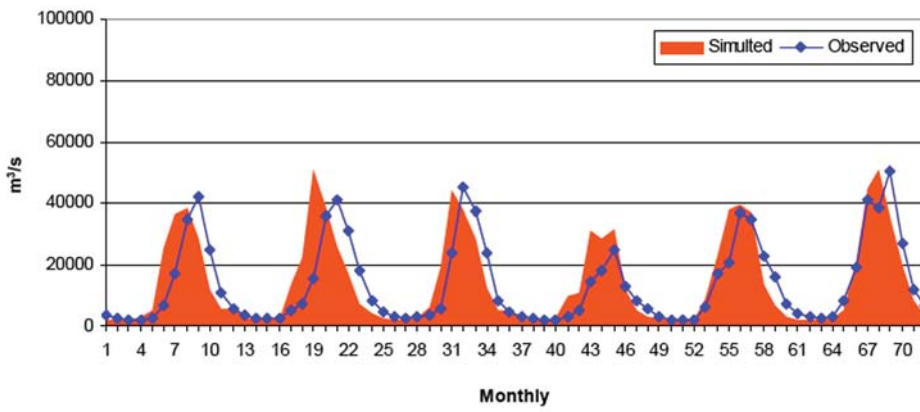


Figure 42. Analysis of adjusted simulation flow and observed flow at Kratie.

## ANNEX E: HYDRODYNAMIC MODELLING FOR FLOODPLAINS – EIA 3D MODEL

The Lower Mekong Basin (LMB) model created within the WUP-FIN Project ([www.eia.fi/wup-fin](http://www.eia.fi/wup-fin)) covers the Mekong Basin from Kratie to the South China Sea including parts of the coastal areas of the Vietnamese Delta. The main parts of the model are Cambodian floodplains, Tonle Sap Lake and Floodplain and Mekong Delta. In total the model covers 448 km x 626 km area of the Lower Mekong Basin with grid resolution of 1 km x 1 km.

The EIA 3D model system is fully three-dimensional model based on rectangular grid representation. The model system accommodates meteorological, hydrological, topographic, land use and infrastructure characteristics of any modelling area and produces 3D hydrodynamics and water quality. The modelling platform including data processing, model control, GIS, database control, model data products and visualization is de-coupled from the actual model engines. The model is able to describe the 3-dimensional characteristics of the flooding, flow, water quality, erosion and sedimentation in the lakes, reservoirs, river channels and floodplains (Koponen

et al. 2005; MRC/WUP-FIN, 2007b). The EIA 3D model is been developed by Environmental Impact Assessment Centre of Finland Ltd (EIA Ltd. – [www.eia.fi](http://www.eia.fi)).

As an input data the model uses following datasets:

- Digital Elevation Model (DEM), see Figure 44
- Landuse map (see Figure 45) to define the roughness parameters in the floodplain
- Boundary conditions (flow, water level & wind – see Figure 44)
  - Flow boundaries in Kratie (A) and Tonle Sap tributaries (B)
  - Water level boundary in South China Sea (C)
  - Wind conditions at the South China Sea
- Various computational parameters

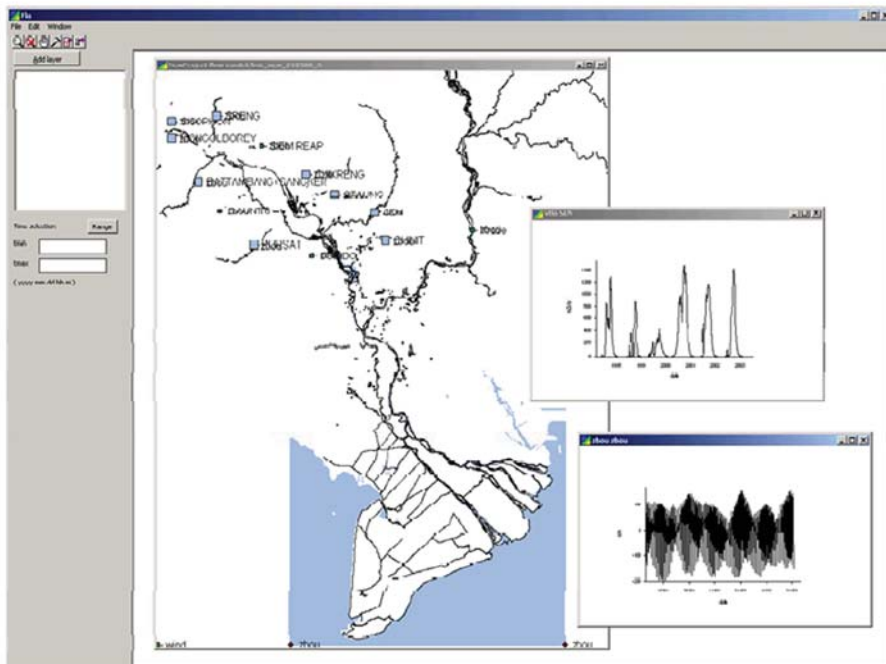


Figure 43. Graphical User Interface (GUI) of the LMB floodplain model application.

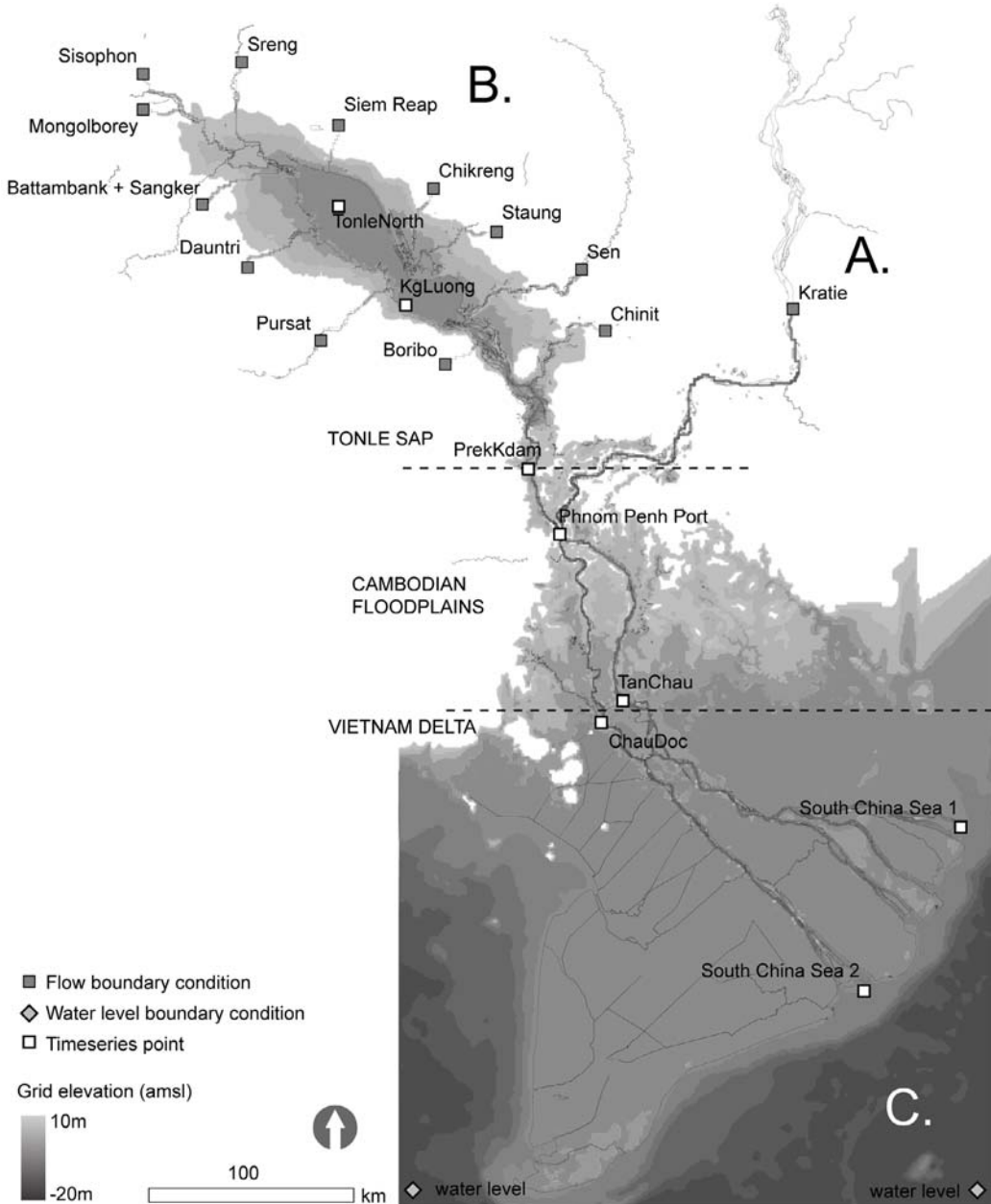


Figure 44. Digital elevation model for the model area and model boundary conditions: A: Flow at Kratie; B: Flow from Tonle Sap tributaries; and C: Sea level at South China Sea.

As and output the model gives following data, among other:

- Flooding characteristics (field and point data)
- 3D currents (field and point data)
- Salinity intrusion (field and point data)
- (suspended sediments and sedimentation)

### E.1 Calibration

The friction parameters of the model, i.e. bottom friction and vegetation drag for different types of land use, were calibrated against observations of water level at Kampong Luong in Tonle Sap Lake in water years 1997–2000. Bottom friction was calibrated to be 0.015, and the vegetation drag was calibrated at 0 to 0.2 depending on the type of land use. Figure 46 shows the observed and simulated water levels in Tonle Sap Lake. The water years 1997–2000 were chosen in order to include different kinds of water years: dry, wet and average

years. Each water year was separately simulated, and the initial water level was set at 1 m amsl in the whole modelling area for every simulated year. The aim was to reproduce the flood pulse as accurately as possible without over-predicting the water levels in the dry season too much.

### E.2 Validation results

The model was validated against water levels at Phnom Penh port near the Chaktomuk confluence and at Tan Chau in the border of Cambodia and Vietnam in water years 1997–2000. The model was able to simulate the rise of the flood satisfactorily, but the drying of the floodplains was too slow and water levels remained too high during the end of each water year. The water levels were also consistently over-predicted in 1998, a very dry water year. Drying of the floodplains could not be enhanced by including some of the main drainage channels of the Mekong Delta in the model.

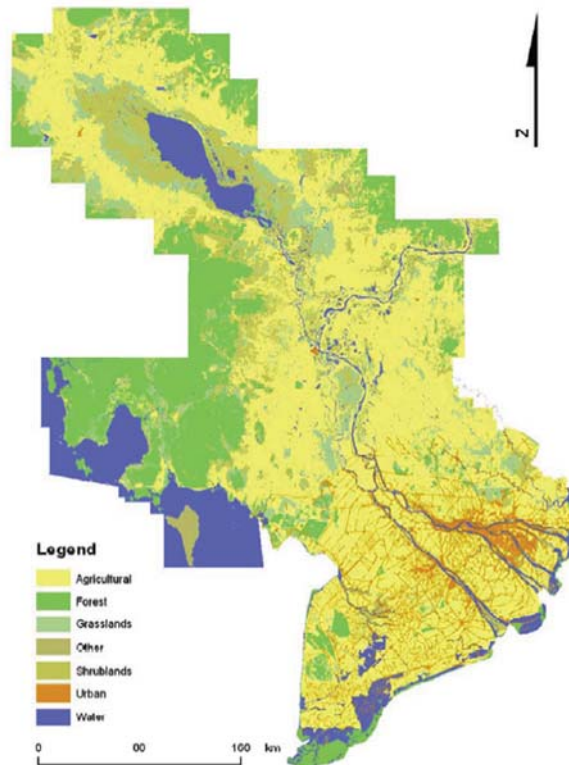


Figure 45. Landuse map for the LMB floodplains.



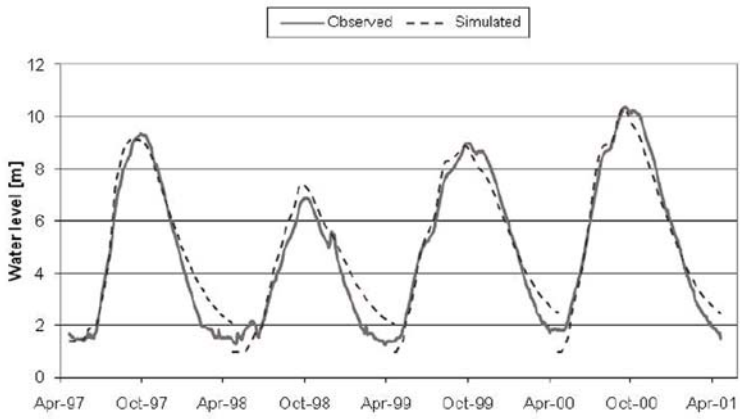


Figure 46. Observed and simulated water levels at Kampong Luong in Tonle Sap Lake during water years 1997–2000.

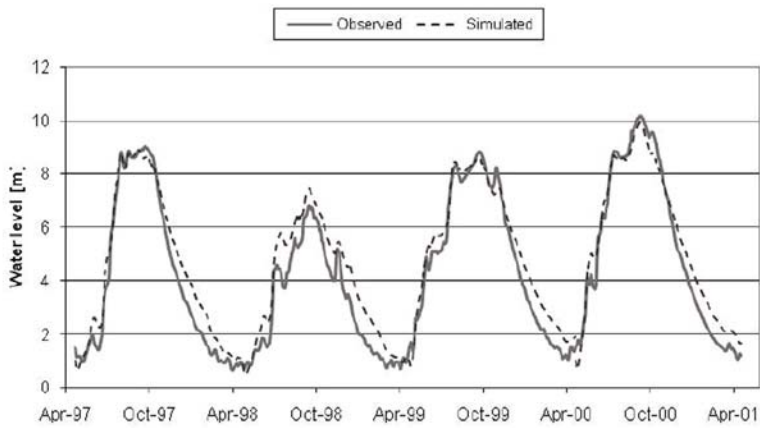


Figure 47. Observed and simulated water levels at Phnom Penh port during water years 1997–2000.

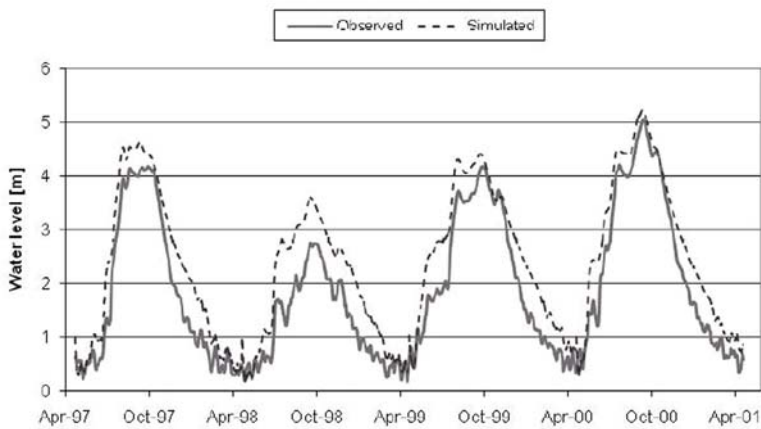


Figure 48. Observed and simulated water levels at Tan Chau during water years 1997–2000.

## ANNEX F: HYDROLOGICAL IMPACT ASSESMENT FOR THE TONLE SAP AREA

The Tonle Sap area is one of the most important and critical parts of the Mekong system due to its unexceptional water regime, unique flood pulse –dependent ecosystem and high fish production (MRCS/WUP-FIN 2007, Keskinen et al. 2007). For the same reason, it is also considered as a particular vulnerable area for potential changes in the Mekong's flow. For this reason, the potential hydrological impacts of different climate change scenarios were studied with a specific detail for the Tonle Sap area and presented in more detailed below.

### F.1 Water levels

In the Tonle Sap system, year-to-year variations in water levels are pronounced (MRCS/WUP-FIN 2007). Thus, in this study, the impacts of climate change on flood pulse were modelled for the driest, wettest and average water year of each decade between 2010 and 2049 in order to look at the changes in the whole range of potential flood pulse conditions and not only in the average conditions. The impacts of two different climate scenarios, namely sea level rise (SEA) and changed basin hydrology (BASIN) were modelled separately as well as cumulatively (BASIN+SEA).

The results of the hydrological impact analysis of these three different climate scenarios are summarised in Table 3, while the hydrograph for the baseline period (1995-2004) and simulated future decades (2010s, 2020s, 2030s, 2040s) are presented in Figure 49.

The modelling results indicate that annual average water level of Tonle Sap Lake increases for almost all of the simulated climate scenarios. Particularly the period of low water levels during the dry season i.e. between February and July show consistently higher average water levels in the future for all types of water years. Average water level in the period of high water levels between August and January is also notably higher in the future for both the average water years and the driest water years.

The relative changes in the water level of the Tonle Sap during the flood season (August-January), as

compared to the water levels during the baseline period (1995-2004), are presented in Figure 50.

Also the period of lower water levels in Tonle Sap Lake appears to become wetter in the future, as indicated by increasing average water level between February and July (Table 3). However, the model could not reliably simulate the months with the lowest water levels, April and May, and it thus remains uncertain whether future water levels will increase or decrease during these driest months. The relative changes in water level, compared to the baseline levels, are presented for the low water season (Feb-Jul) in Figure 51.

### F.2 Flooded area and flood duration

The model results indicate that the Tonle Sap flood pulse will generally become more intense during the first half of the 21st century due to climate change (Figure 53, Figure 54). This is visible when looking at the different climate scenarios; for most of the climate scenarios the average wet season water level will increase, annual maximum water level and maximum flooded area increase, and flooding will last somewhat longer (due to an earlier start date and a later end date) when compared to the baseline period. Also annual average water level and annual cumulative flooded area will be greater in the future for almost all the climate scenarios.

Figure 52 illustrates the cumulative impacts of sea level rise and changed basin hydrology (BASIN+SEA) on the start dates, peak dates and end dates of flood pulse. Flooding is likely to begin earlier in the Tonle Sap system in the future, as is indicated by 10 out of the 12 cumulative impact scenarios. The backward shift of flood start date is particularly notable in the average and driest years. At the same time, the flood end date seems to shift slightly forward in the average and driest years, thus extending the overall duration of future floods.

In the wettest water year of the baseline period, simulated water level did not fall below 2.44 m amsl by the end of the water year, and as a result differences for end dates could not be obtained for the wettest

**Table 3:** Average water levels [cm amsl] in the Tonle Sap for the baseline period (1995-2004) and their changes in future decades compared to the baseline. See Chapter 3 for explanations on water year and climate scenarios.

AVERAGE WATER YEAR	AVERAGE WATER LEVEL AND THEIR CHANGES [CM]		LEVEL AND THEIR CHANGES [CM]		
	DECADE	CLIMATE SCENARIO	FEB-JUL	AUG-JAN	AVERAGE
AVERAGE WATER YEAR	Baseline		243	728	488
	2010s	SEA	+1	+0.1	+0.7
		BASIN	+34	+16	+25
		BASIN+SEA	+35	+16	+25
	2020s	SEA	+2	+0.2	+1
		BASIN	-2	+26	+12
		BASIN+SEA	-0.3	+26	+13
	2030s	SEA	+3	+0.3	+1
		BASIN	+6	+15	+11
		BASIN+SEA	+8	+15	+12
	2040s	SEA	+3	+0.4	+2
		BASIN	+23	+40	+31
BASIN+SEA		+25	+40	+33	
DRIEST WATER YEAR	Baseline		223	571	399
	2010s	SEA	+1	+0.3	+0.7
		BASIN	+32	-8	+12
		BASIN+SEA	+32	-7	+12
	2020s	SEA	+2	+0.5	+1
		BASIN	-23	+8	-7
		BASIN+SEA	-23	+8	-7
	2030s	SEA	+3	+0.8	+2
		BASIN	+24	+47	+36
		BASIN+SEA	+26	+47	+36
	2040s	SEA	+3	+1	+2
		BASIN	+17	+14	+15
BASIN+SEA		+19	+14	+16	
WETTEST WATER YEAR	Baseline		367	817	594
	2010s	SEA	+0.7	0	+0.4
		BASIN	+65	-43	+10
		BASIN+SEA	+66	-44	+11
	2020s	SEA	+1	0	+0.5
		BASIN	+86	-24	+30
		BASIN+SEA	+86	-24	+30
	2030s	SEA	+1	0	+0.6
		BASIN	+4	-9	-3
		BASIN+SEA	+5	-9	-2
	2040s	SEA	+2	0	+0.8
		BASIN	+28	+7	+17
BASIN+SEA		+29	+7	+18	

water years. All in all, the simulated flood end dates cannot be considered to be entirely reliable since the drying of the Tonle Sap floodplains was too slow in the EIA 3D model, and should therefore be regarded as indicators revealing the direction of change. The peak date of the flood pulse seems to occur later in the average water years, earlier in the

driest water years and either earlier or later in the wettest water years. The greatest and most consistent changes seem to occur for the average and driest water years; however, this might be partly explained by the baseline period as the wettest year (2000) of the baseline period was unexceptionally wet.

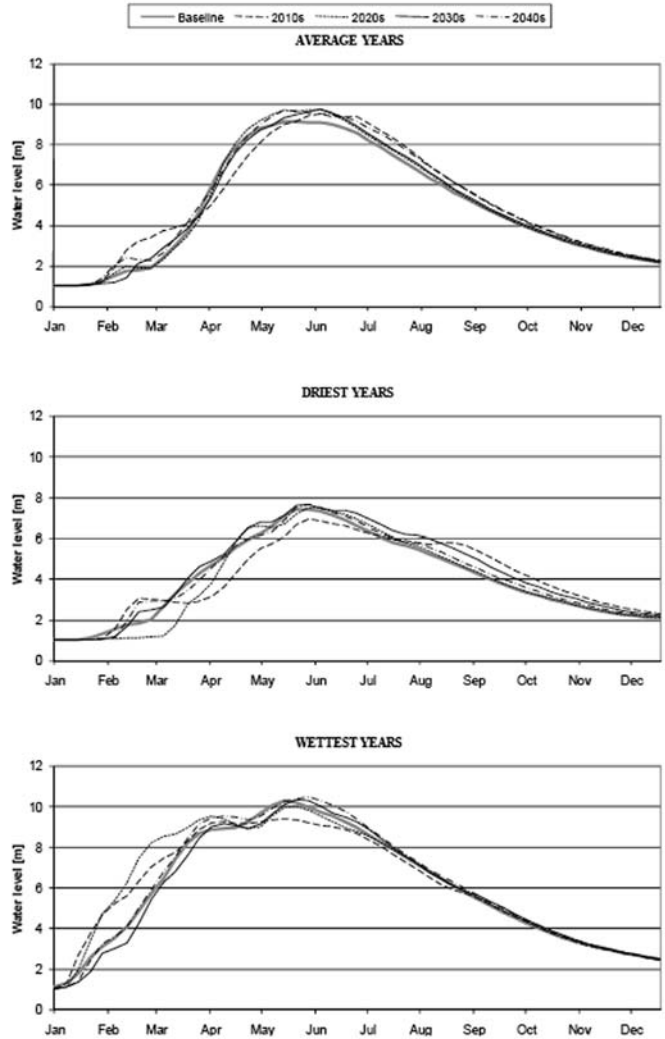


Figure 49. Simulated water levels of the Tonle Sap Lake in different future decades under the changed basin hydrology (BASIN) climate scenario.

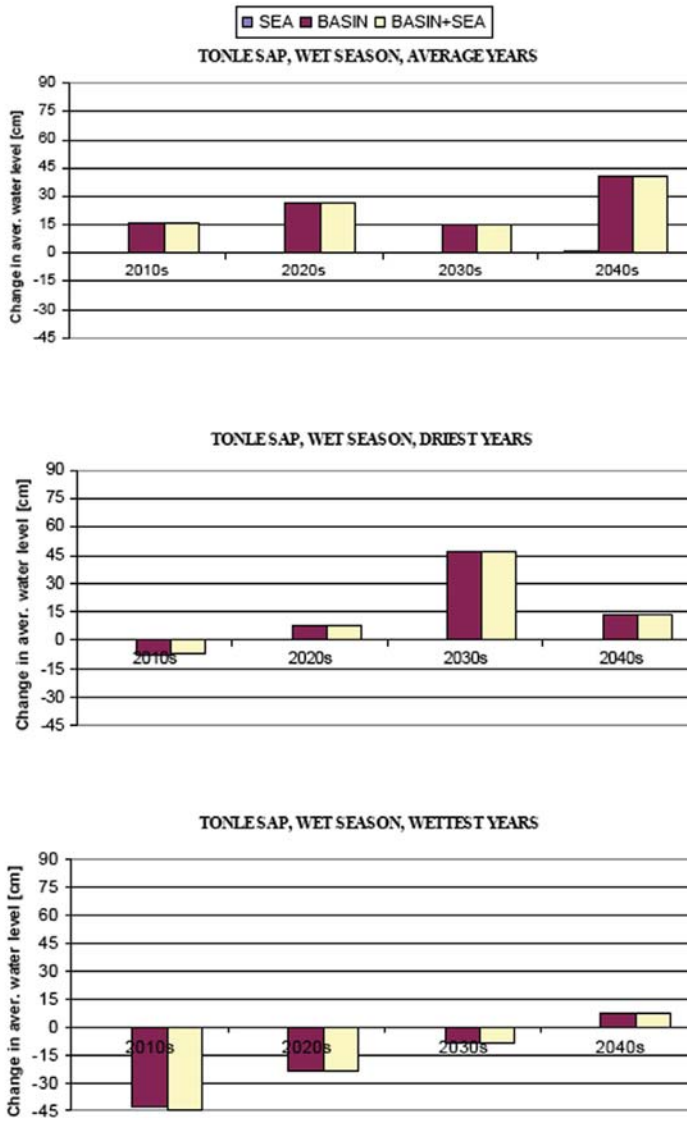


Figure 50. The changes in the Tonle Sap water levels during the flood season compared to the water levels of baseline period (1995-2004).

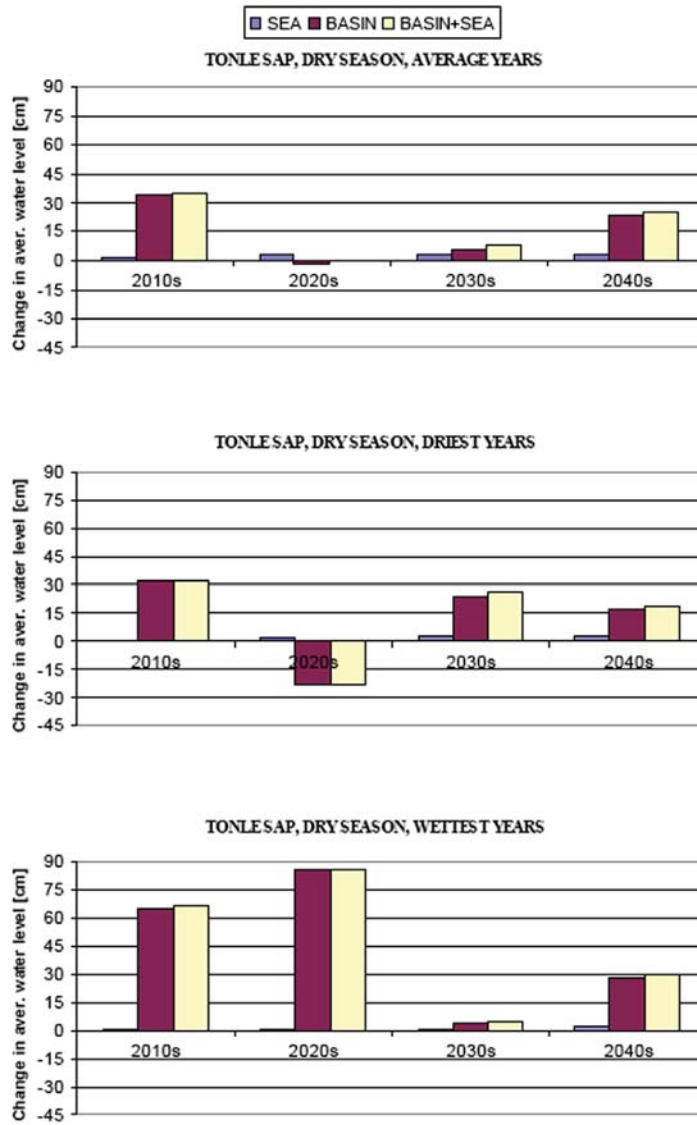


Figure 51. The changes in water levels during the low water season compared to the baseline water levels.

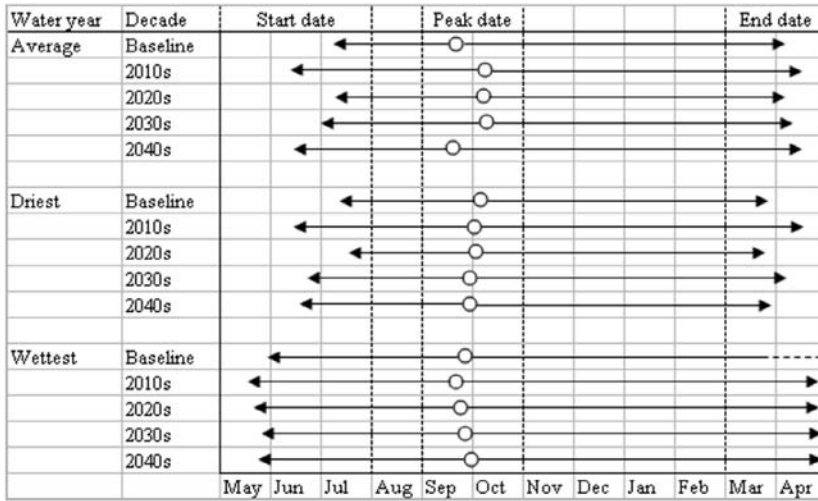


Figure 52. Start, peak and end dates of flooding in the Tonle Sap lake–floodplain system under the cumulative impact of sea level rise and changed basin hydrology (BASIN+SEA).

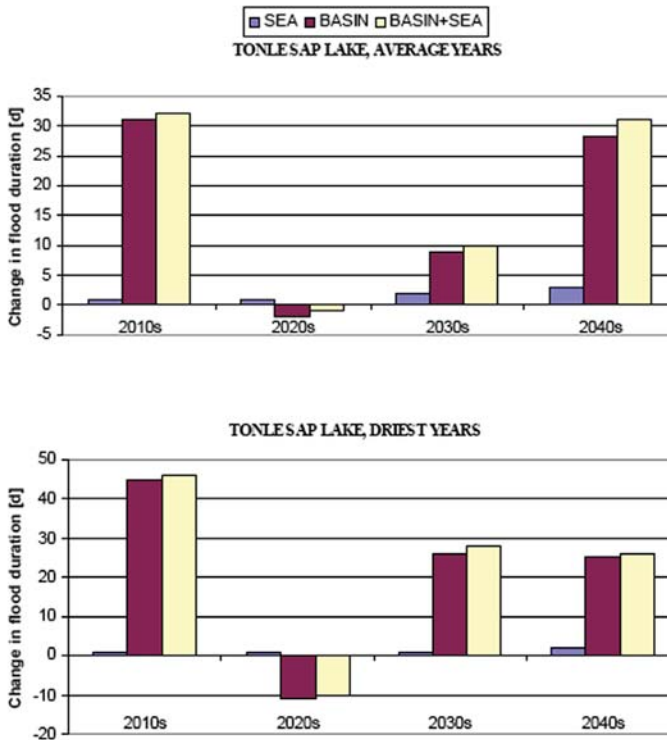


Figure 53. Changes in maximum flooded area compared to the baseline period (1995–2004) for different climate scenarios.

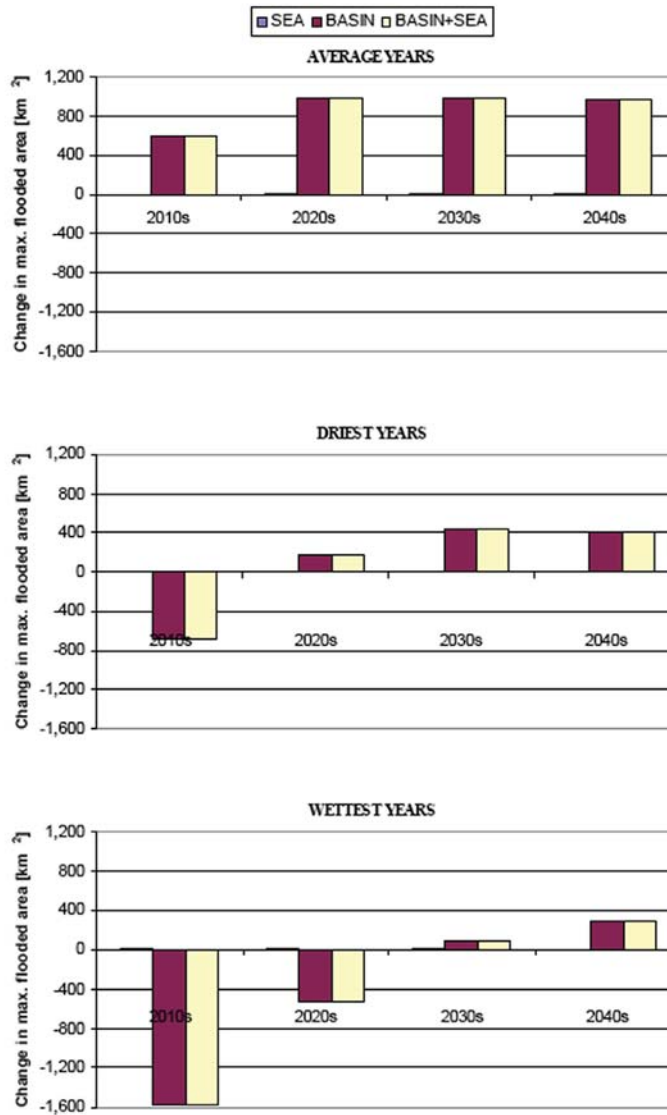


Figure 54. Changes in flood duration compared to the baseline period (1995-2004) for different climate scenarios.



### F.3 Summary of the results

The modelling results of the hydrological impact of different climate scenarios indicate that out of the two climate scenario the changed basin hydrology (BASIN) has much greater impact on the Tonle Sap flood pulse than the sea level rise (SEA). The impacts of sea level rise are more notable when the water levels are lower, for example in the dry season compared to the wet season and in the driest water years compared to the wettest water years.

On the other hand, the impacts caused by sea level rise scenario are very consistent throughout

the simulated period, increasing in magnitude decade by decade, whereas the impacts of changed basin hydrology scenario are more varied in both magnitude and direction of change. This is understandable considering the nature of the processes: sea level does not undergo as remarkable annual or decadal fluctuations as e.g. rainfall or other hydrological and meteorological variables. Due to the relatively small impacts of sea level rise in the Tonle Sap area, the results of the cumulative impact scenario (BASIN+SEA) are almost equal to those of the changed basin hydrology scenario (BASIN) alone. The results are summarised in Table 4.

**Table 4.** Average changes in the Tonle Sap flood pulse characteristics and other hydrological variables for the period of 2010-2049 compared to baseline period (1995-2004).

CHARACTERISTIC	SEA	BASIN	BASIN+SEA
Average water level (Feb–Jul) [cm]	+2	+25	+26
Average water level (Aug–Jan) [cm]	+0.3	+7	+7
Annual cumulative flooded area [1000 km <sup>2</sup> ]	+5	+81	+84
Annual maximum water level [cm]	+0.5	+11	+11
Annual maximum flooded area [km <sup>2</sup> ]	+8	+181	+182
Flood start date [d]	-0.3	-12	-13
Flood peak date [d]	0	+2	+2
Flood end date [d]	+1	+4	+5
Flood duration [d]	+2	+19	+20

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## WATER AND CLIMATE CHANGE IN THE LOWER MEKONG BASIN:

### Diagnosis & recommendations for adaptation

Adaptation to climate change has become one of the focal points of current development discussion. There are naturally very good reasons for this, as the impacts of climate change will in many occasions magnify the challenges that people are already facing.

This book summarises the main findings from an 11-month, multidisciplinary research project that looked at climate change impacts and adaptation in the Mekong River Basin in Southeast Asia. The book illustrates the estimated impacts caused by climate change in the Tonle Sap area and the Mekong Delta, and discusses the possibilities to adapt to them through analysis of local adaptation strategies and national policies.

The research findings highlight the central role that hydrological cycle has in mediating the impacts of climate change to both ecosystems and societies. The findings also clearly point out that climate change must not be studied in isolation, as there are several other factors that are likely to induce changes in hydrological cycle, and consequently on environment and livelihoods. In the Mekong, most important such “change factor” is the already on-going hydropower development that is likely to cause at least as radical changes as climate change but with much shorter timeframe.

It is therefore concluded that climate change adaptation must build more strongly on cumulative impact assessment and focus its efforts on general environmental changes likely to occur in both shorter and longer term due to different factors. It is also crucial to recognise that climate change adaptation is a dynamic, development-orientated process that instead of single solutions should be based on long-term view considering also broader socio-political dynamics. To enable this, we propose an area-based –rather than the dominant sector-based– approach for climate change adaptation.

This book together with other project publications is available also electronically at the project’s web site at: <http://users.tkk.fi/u/mkummu/water&cc/>