Climate change and water resources in the Lower Mekong River Basin: putting adaptation into the context

M. Keskinen, S. Chinvanno, M. Kummu, P. Nuorteva, A. Snidvongs, O. Varis and K. Västilä

ABSTRACT

Adaptation to climate change has become one of the focal points of current development discussion. This article summarises the findings from a multidisciplinary research project looking at climate change impacts and adaptation in the Mekong River Basin in Southeast Asia. The research highlights the central role that the hydrological cycle has in mediating climate change impacts on ecosystems and societies. The findings indicate that climate change should not be studied in isolation, as there are several other factors that are affecting the hydrological cycle. In the Mekong, the most important such factor is the on-going hydropower development that is likely to induce changes at least as radical as climate change, but with shorter timescales. The article concludes that climate change adaptation should broaden its view to consider environmental changes likely to occur due to different factors at various spatial and temporal scales. It is also important to recognise that climate change adaptation is a dynamic, development-orientated process that should consider also broader socio-political context. To enable this, we propose that an area-based adaptation approach should be used more actively to complement the dominant sector-based approaches.

Key words | adaptation policies, climate change adaptation, livelihoods, Mekong Delta, Tonle Sap, water resources management

ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D</td>
<td>Three-Dimensional</td>
</tr>
<tr>
<td>CC</td>
<td>Climate Change</td>
</tr>
<tr>
<td>CCCO</td>
<td>Cambodian Climate Change Office</td>
</tr>
<tr>
<td>DIVA</td>
<td>Dynamic and Interactive Vulnerability Assessment; a method for modular integrated modelling</td>
</tr>
<tr>
<td>ECHAM</td>
<td>An atmospheric general circulation model</td>
</tr>
<tr>
<td>EEA</td>
<td>European Environment Agency</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment Center of Finland Ltd.</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>IUCN</td>
<td>International Union for Conservation of Nature</td>
</tr>
<tr>
<td>MOIT</td>
<td>Ministry of Industry and Trade, Vietnam</td>
</tr>
<tr>
<td>MONRE</td>
<td>Ministry of Natural Resources and Environment, Vietnam</td>
</tr>
<tr>
<td>MRC</td>
<td>Mekong River Commission</td>
</tr>
<tr>
<td>MRCS</td>
<td>Mekong River Commission Secretariat</td>
</tr>
<tr>
<td>NAPA</td>
<td>National Adaptation Program of Action to Climate Change</td>
</tr>
<tr>
<td>POM</td>
<td>Princeton Ocean Model</td>
</tr>
<tr>
<td>PRECIS</td>
<td>Providing REgional Climates for Impacts Studies; a regional climate modelling system</td>
</tr>
<tr>
<td>SEA START RC</td>
<td>Southeast Asia START Regional Center</td>
</tr>
<tr>
<td>SEI</td>
<td>Stockholm Environment Institute</td>
</tr>
</tbody>
</table>

doi: 10.2166/wcc.2010.009
INTRODUCTION

Climate change adaptation and water

Current 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 the hydrological cycle as, for example, floods, droughts and storms (UNDP 2006; Falkenmark 2007; IPCC 2007a; Leary et al. 2008a; Ludwig & Moench 2009; Michel & Pandya 2009). The most recent World Water Development Report notes that “climate change can directly affect the hydrologic cycle and, through it, the quantity and quality of water resources”, concluding that climate change is going to have a direct impact on water availability for flora and fauna as well as for diverse human uses (World Water Assessment Programme 2009: 68).

While the magnitude of the estimated climate change impacts depends on the scenarios used, increases in global temperature are in any case expected to continue for decades, even if greenhouse gas emissions were stabilised today (EEA 2007; IPCC 2007b). Actions have to be taken to respond to these impacts, and the discussion about climate change has therefore shifted from mitigation towards adaptation to climate change. The increasing emphasis on adaptation is also apparent in recent climate change-related publications and events, most importantly in the assessment reports of the Intergovernmental Panel on Climate Change (IPCC 2007a) as well as in the 15th Conference of the Parties of the United Nations Framework Convention on Climate Change held in December 2009 in Copenhagen.

The impacts of climate change are estimated to be particularly severe in many developing countries, including the coastal zones and the areas prone to flooding and drought (UNDP 2006; IPCC 2007a; Michel & Pandya 2009; World Water Assessment Programme 2009). The climate change impacts in these areas are likely to bring new challenges as well as to magnify already existing ones, impacting both the livelihoods and food security. Yet, the implications of changing climate are not distributed equally and some groups are likely to lose—and some groups gain—more than others. Given the multiple linkages that climate change has with development, climate change adaptation has thus become one of the focal points of current development discussion as well (Le Blanc 2009).

This is also the situation in the Mekong River Basin in Southeast Asia, where the issue of climate change has entered both the national and regional discussion. There are naturally good reasons for this, as climate change is estimated to have a significant impact on the region’s water resources, and consequently on the livelihoods of millions of people (Chinvanno et al. 2008; Eastham et al. 2008; Resurreccion et al. 2008; TKK & SEA START RC 2009). Climate change and responses to it are addressed in different arenas, and the resources available for adaptation are increasing rapidly. At the same time, however, there is a danger that the current ‘climate change hype’ neglects the broader context in which the adaptation takes place, leading to overlaps as well as to actions that are not really improving the overall capacity to respond to the multiple environmental changes the region is facing. The actions responding to climate change impacts may also lead to growing social injustices, putting different social groups in an increasingly unequal position (Lebel 2007; Resurreccion et al. 2008).

This article presents the key findings from an 11-month multidisciplinary research project ‘Water and Climate Change in the Lower Mekong Basin: Diagnosis & recommendations for adaptation’ (TKK & SEA START RC 2009). The research was carried out by the Helsinki University of Technology (now part of Aalto University),
Finland and Southeast Asia START Regional Center at the Chulalongkorn University, Thailand in cooperation with several partners. Due to its short duration, the project was not able to cover the entire Mekong River Basin or all the linkages between climate and water. Instead, the project focused on the hydrological impacts of climate change as well as related adaptation strategies in the Tonle Sap Lake area of Cambodia and the Mekong Delta of Vietnam, using results from just one climate model. The project can thus be seen as a kind of scoping study providing some indicative results about climate change adaptation in the two areas, helping thereby to recognise the possibilities for future research and action. The research aims to provide an overview of estimated climate change impacts in these areas together with the broader context within which the impacts are taking place. As the more detailed descriptions of the research methodology and findings are presented elsewhere (TKK & SEA START RC 2008, 2009; Nuorteva 2009; Västilä 2009; Nuorteva et al. 2010; Västilä et al. 2010), this article focuses on more general findings as well as on their implications to the general discussion about climate change adaptation.

**The Mekong River Basin**

The Mekong River in Southeast Asia is among the greatest rivers of the world: both its estimated length (4,909 km) and its mean annual volume (475 km³) make it the world’s tenth largest (MRC 2005; Shaochuang et al. 2007). The Mekong is also among the world’s most pristine large rivers, supporting an exceptionally diverse and productive freshwater ecosystem that provides livelihood and food for millions of people. Most important water-related resources in the basin are rice and fish as well as other aquatic animals and plants (MRC 2005a).

Six riparian countries share the Mekong River Basin: Cambodia, China, Laos, Burma/Myanmar, Thailand and Vietnam. The Mekong River and its tributaries have different environmental, economic, social and cultural roles in the six countries. For the primarily rural economies of Cambodia, Laos and the Mekong Delta of Vietnam, the river is the lifeline of the local people as it supports directly the livelihoods of millions of fishers and farmers. The river and its floodplains are particularly important for the Lower Mekong floodplains downstream from the Cambodian provincial town of Kratie; in this area the annual rhythm of the river is most visible as the flood waters extend the river to vast floodplains, supporting highly productive fisheries and rice cultivation.

The Mekong River Basin is expected to see an increasing number of water infrastructure developments within the coming decades, particularly in form of large-scale hydropower dams in upper parts of the basin (IUCN et al. 2007; King et al. 2007; MRC 2008a; Middleton et al. 2009). The current impact assessments indicate that these planned hydropower dams are likely to cause significant impacts in the Lower Mekong floodplains and in the Tonle Sap system in particular, affecting both water quantity and quality and consequently the aquatic productivity of the river-floodplain system (MRC/WUP-FIN 2007; Dugan 2008; Keskinen 2008a; Kummu & Sarkkula 2008; Molle et al. 2009). In addition to hydropower dams, the basin is seeing rapid changes in land use as well as intensifying plans for irrigation, flood control structures and other infrastructure such as roads. These diverse changes and plans have drawn considerable attention, as it is feared they will undermine the livelihoods of millions of people by impacting negatively the availability of water-dependent resources, most importantly fish (see e.g. IUCN et al. 2007; MRC/WUP-FIN 2007; Keskinen 2008a; Rowcroft 2008; Molle et al. 2009; Sarkkula et al. 2009).

This article focuses on two very special areas in the Lower Mekong Basin: the Tonle Sap Lake of Cambodia and the Mekong Delta of Vietnam (Figure 1). Both areas are unusual in terms of hydrology: the Tonle Sap has its extraordinary flood pulse system and the Delta possesses the diverse characteristics of deltas including floods, saline water intrusion and strong tides. In both areas people have developed methods for adapting and making use of the exceptional hydrological regime. While in the Tonle Sap the people are still adapted to the natural water regime (Keskinen 2006; MRC/WUP-FIN 2007), in the Delta the decades-long adaptation has actually meant ambitious engineering projects that have resulted in a move from adaptation to the control of delta’s water regime (Biggs 2003; Miller 2005; Käkönen 2008).

The Tonle Sap Lake is known for its flood pulse system with a remarkable but nevertheless rather regular seasonal
variation in the lake’s water volume and level. The flood pulse is closely connected to the Mekong River: during the rainy season part of the Mekong’s floodwaters flow to the lake, and the lake’s surface area quadruples and the water level increases from mere 1 m up to 10 m (MRCS/WUP-FIN 2007). An exceptional and highly productive floodplain ecosystem has been formed, and the Tonle Sap is believed to be among the world’s most productive freshwater ecosystems. The Tonle Sap is also exceptional for a lake of its size, as the impacts of climate change—or any other environmental changes—are felt as a combination of changes in its own basin and that of the Mekong River. The actual ‘impact basin’ of the Tonle Sap Lake is thus not merely the lake basin (86,000 km²), but the entire Mekong River Basin upstream from the Tonle Sap (680,000 km²). This naturally makes the assessment of potential impacts on the area a particular challenge.

The people living in and around the Tonle Sap Lake are well adapted to the remarkable variation of the lake’s water level, living in floating and stilt houses and making use of the resources the flood pulse supports (Poole 2005; Keskinen 2006). Overall, the Tonle Sap Lake and the surrounding floodplains form a source of livelihoods and food for well over million people living in and around the lake. The significance of the Tonle Sap extends, however, much further; it is estimated that up to half of Cambodia’s population benefits directly or indirectly from the lake’s resources, and the Tonle Sap’s high fish production also
bring benefits to other Mekong countries (Bonheur 2001; Bonheur & Lane 2002; MRCS/WUP-FIN 2007).

The Vietnamese side of the Mekong Delta\(^1\) covers an area of around 39,200 km\(^2\) with a total population of over 16 million (SIWRP & VNMC 2003; MRCS/WUP-FIN 2006). The delta is thus much more intensely populated than the Tonle Sap area, with average population density over 400 persons/km\(^2\), compared to approximately 80 persons/km\(^2\) in the Tonle Sap (Keskinen 2008b). The delta is a low-level plain not more than three meters above sea level at any point, and 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. The delta is crisscrossed by a maze of canals and rivers that enable delta’s remarkable agricultural production and also serve as important means of transportation. The vast rice fields together with other agricultural as well as aquacultural products make up the core of the region’s economy. Rice cultivation is of major importance to Vietnam, and as up to half of the national production and 70% of the exported rice comes from the Mekong Delta, the area is often described as the rice basket of entire Vietnam (Miller 2003; MRCS/WUP-FIN 2006; Kääkönen 2008).

**METHODS**

**Assessing the impacts and adaptation capacity**

The research presented in this article builds on a multidisciplinary approach that makes use of various approaches and methods (Figure 2). Two interlinked modelling exercises formed the core of the research; one exercise focused on modelling and downscaling of selected climate change scenarios for the Mekong Region, and the other on modelling the impacts of these changes with the help of hydrological and hydrodynamic models. The objective of the modelling exercises was to estimate how climate change alters the flood pulse (Junk et al. 1989) characteristics in the Lower Mekong floodplains in the first half of the 21st Century, with a focus on the Tonle Sap Lake area and the Mekong Delta of Vietnam. The modelling approach is briefly explained next, while a more thorough description is provided by Västilä (2009) and Västilä et al. (2010).

The models run for two periods: the baseline (years vary depending on data availability) and the future (2010–2049). The output from one model was converted into the input for another model with the so-called delta change method, where the changes between the simulated baseline and the

---

\(^1\) The definition of the entire Mekong Delta varies, with estimates of its total area ranging from 49,000 km\(^2\) (SIWRP & VNMC 2003) up to 65,000 km\(^2\) (MRC 2003b). Commonly, however, the delta is defined to consist of the area downstream from Cambodian capital of Phnom Penh and the delta can thus be divided into two parts: Cambodian and Vietnamese. In this article we use—similarly to many other publications—the general term ‘Mekong Delta’ also to refer just to the Vietnamese part of the delta.
simulated future were imposed on the observed input time series. The climatic changes were simulated by dynamically downsampling data from the ECHAM4 atmospheric–ocean general circulation model runs (Roecnner et al. 1996) with the PRECIS regional climate model (Jones et al. 2004) under the SRES A2 emissions scenario (Nakićenović & Swart 2000). The PRECIS output included rainfall, temperature, wind speed and wind direction.

The downscaled temperature and precipitation data were used as an input to a hydrological model (Variable Infiltration Capacity model, VIC). The VIC model covered the Upper Mekong Basin and produced the discharge of the Mekong (at Kratie, location shown in Figure 1) as an output. The downscaled wind speed and wind direction data were used as an input to an ocean circulation model (Princeton Ocean Model, POM), which simulated the local sea level fluctuations at the mouth of the Mekong Delta. The future sea level time series were produced by combining the POM results with the estimated global sea level rise obtained with the so-called DIVA tool (Hinkel 2005).

A three-dimensional hydrodynamic model was chosen for flood pulse simulation as it is more suitable for simulating complex floodplain flows than simpler one-dimensional models. The EIA 3D hydrodynamic model (Koponen et al. 2005; Kummu et al. 2006; MRCS/WUP-FIN 2008) was run for three types of hydrological years: the decade’s wettest, driest and average hydrological years in the baseline decade (1995–2004) and in the 2010s–2040s. Hydrological year was defined based on the flood timing, starting on May 1st and ending on April 30th. The baseline was compared with the following three scenarios: 1) climate-change induced alterations in basin hydrology upstream of Kratie (river flow, obtained from the VIC model), 2) sea level rise (obtained from the POM and DIVA models), and 3) their cumulative impacts. Three scenarios simulated for three types of hydrological years produced altogether nine scenario cases. Simulated flood pulse characteristics, such as average and maximum water levels and the duration and timing of the flooding, were compared between the baseline and the scenario cases (TKK & SEA START RC 2009; Västilä et al. 2010).

The modelling exercises were complemented with analyses of national adaptation policies in Cambodia and Vietnam, a review of regional adaptation initiatives as well as a study on livelihood resilience and local adaptation strategies in the Tonle Sap area. In addition, a one-day stakeholder consultation workshop was carried out in the Mekong Delta, discussing the estimated climate change impacts and possibilities for adaptation in the area. While the study on national and regional adaptation plans was based on review of existing literature (TKK & SEA START RC 2008, 2009), the livelihood analysis built on key informant interviews in six study villages around the Tonle Sap Lake. To understand the differences in different parts of the floodplain, the study villages were selected so that they formed two transects—or crosscuts—across the floodplain, with three villages in both transects: one close to the lake, another one in the middle of the floodplains, and the third one in the upper parts of the floodplain close to the National Roads surrounding the lake (Nuorteva et al. 2010).

The livelihood analysis looked at climate change adaptation through the concepts of vulnerability and resilience (Holling 1973; Adger 2000; Cutter et al. 2008; World Resources Institute 2008). As noted by Cutter et al. (2008), vulnerability is a function of the exposure and sensitivity of system, while resilience refers then to the ability of a social system to respond to and recover from disasters. Resilience therefore looks at the ability of social-ecological systems to cope with changing situations, and climate change adaptation was thus considered as one change factor among many, rather than as a completely new paradigm. At the end of the research, the findings from all research components—modelling, review of adaptation policies, livelihood analysis—were put together, and overall recommendations synthesising these findings formulated (TKK & SEA START RC 2009). This article presents a summary on these key conclusions.

RESULTS

Climate change impacts and adaptation in the Mekong

Climate change scenarios: warmer and wetter

The results from the climate modelling used in this research indicate that the Mekong Region will become slightly warmer, but the duration of warm periods will be greater and cover a much wider area. The greatest changes were
simulated for the northern areas of the Mekong River Basin. The annual rainfall in the basin was projected to grow on average by some 4% during the study period. These estimated changes will, however, be spread unevenly, with rainfall estimated to increase in the upper parts of the basin but to decrease in the Lower Mekong floodplains. The overall increasing trend results from increasing rainfall intensity, as the length of the rainy season is estimated to be more or less the same as at present (TKK & SEA START RC 2009; Västilä et al. 2010).

In addition to the impacts of the changes in temperature and rainfall, the sea level rise is estimated to have a significant impact particularly in the Mekong Delta, affecting both the flooding and the saline water intrusion. While the sea level rise has clearly the most significant impacts for the hydrological changes in the delta, their impact is negligible in the Tonle Sap where the impacts of the changed basin hydrology (i.e. the changes occurring within the entire Mekong River Basin) due to changing climate dominate. The change in sea level is very consistent throughout the study period, increasing in magnitude decade by decade, whereas the impacts of changed basin hydrology are more varied in both magnitude and direction of change (TKK & SEA START RC 2009).

Hydrological and hydrodynamic changes:
more intensive flooding

A majority of the nine scenario cases used for assessing the climate change impacts to Mekong’s flow produced similar, clear changes in flooding patterns. In the first half of the 21st century, the flood pulse in the Tonle Sap and Cambodian floodplains as well as in the Mekong Delta is likely to be greater than in the baseline decade. Annual average water level was projected to rise in every scenario case both in the Tonle Sap area and the Mekong Delta. The projected rise was up to 20 cm, increasing also the annual cumulative flooded area. Flood duration increased in all the scenario cases by 0–9%, i.e. between 1 and 23 days. It is also notable that the models indicated increase in the average dry-season water level of the Tonle Sap (Västilä 2009; Västilä et al. 2010). However, as the EIA 3D model was not able to simulate the dry-season water level very reliably, this result should be regarded as indicative only.

All the simulated flood pulse characteristics indicate that the average and driest hydrological years are likely to be wetter in the future. The wettest hydrological years also show increases in the average and dry-season flood pulse characteristics, but undergo decreases in terms of high water characteristics. For instance, the average high water level increases by 1–25 cm in the average and driest years, whereas it decreases by up to 27 cm in the wettest years in comparison to the baseline (Västilä et al. 2010). Overall, in both the Tonle Sap and the Mekong Delta the estimated climate change impacts are being felt through regional (i.e. basin-wide) as well as local changes.

National adaptation plans & policies: focus on sectoral approaches

Adaptation to climate change can be done through a range of measures, including technological (e.g. protective infrastructure and early warning systems), behavioural (e.g. changes in consumption or food choices), managerial (e.g. changes in agricultural practices) as well as policies (e.g. new regulations for planning) (IPCC 2007a; Francisco 2008). This research focused on adaptation policies that can be seen to provide the overall framework for the different adaptation measures.

In both Cambodia and Vietnam, climate change adaptation policies and plans are coordinated by the respective environmental ministries. In Cambodia, the Cambodian Climate Change Office (CCCO) under the Ministry of Environment is responsible for climate change adaptation. The main programme guiding adaptation is the National Adaptation Program of Action to Climate Change (NAPA) that provides a framework for coordination and implementation of adaptation initiatives (Ministry of Environment 2006). The NAPA takes a primarily sectoral approach for adaptation, and recognises four priority sectors for climate change adaptation in Cambodia: agriculture, forestry, human health, and coastal zone. In addition, water resources sector is included as a fifth, crosscutting priority sector due to its close linkages with the other priority sectors and its importance for Cambodia’s overall development. It is notable that the NAPA puts little emphasis on fisheries, despite their remarkable social and economic importance and clear vulnerability to environmental and
climatic changes (Resurreccion et al. 2008; TKK & SEA START RC 2009).

Vietnam is considered as one of the world’s most vulnerable countries to climate change impacts because of its heavy and variable rainfall, long low lying coastline and exposure to typhoons and storms (MONRE et al. 2008). Policies to assess and to respond to climate change impacts are therefore high in the government's agenda. The adaptation actions are guided by the National Target Program to Respond to Climate Change that was approved in December 2008 and places the Ministry of Natural Resources and Environment as the lead agency for its implementation. The programme aims to enhance Vietnam’s capacity to respond to climate change, and its objective is to “assess climate change impacts on sectors and regions in specific periods and to develop feasible action plans to effectively respond to climate change in the short-term and long-term” (The Socialist Republic of Vietnam 2008: 2). The assessment of climate change impacts and the identification of adaptation measures are in the National Target Program organised mainly on a sectoral basis, emphasising the role of different ministries in these actions.

In addition to national plans, there exist regional initiatives related to climate change adaptation (see e.g. MRC 2008b; TKK & SEA START RC 2008; SEI 2009; WWF 2009). For instance the Mekong River Commission initiated in 2008 its own climate change and adaptation initiative for the Lower Mekong Basin, highlighting that the climate change is fundamentally a basin-wide issue. The initiative aims to improve the capacity of the riparian governments to manage and adapt to climate change by developing scientific data and analytical tools for the projection of future climate impacts and by identifying adaptation strategies to these impacts (MRC 2008b).

Livelihoods and local adaptation strategies: increasing vulnerability

The findings from the field research looking at livelihood resilience and adaptation capacity in the Tonle Sap area indicate that people are generally well adapted to remarkable seasonal variation in the lake’s waters. However, their adaptation capacity towards unusual environmental changes such as extraordinary high floods and sudden storms, both expected to intensify due to climate change, is limited. The reasons for the low adaptation capacity and resulting high vulnerability seem to be related to the rather homogenous livelihood structures, weak opportunities to diversify the livelihood sources, institutional and governance challenges as well as decreasing availability of natural resources. The vulnerabilities were relatively similar in all study villages, including both the floating villages in the lake and the agricultural villages further up in the floodplains (Nuorteva 2009; Nuorteva et al. 2010). The research findings also point out that the adaptation capacity of the poorest groups is particularly low, as their already low living standards and limited asset-base intensifies their vulnerability to challenges and changes. This seems to be the case also in other countries in the region, including Vietnam (Chaudhry & Ruyschaert 2007; Resurreccion et al. 2008).

The findings from the field research indicate that among the most efficient strategies for adapting to the impacts of environmental changes is to increase the general standards of living and the prerequisites to maintain a productive livelihood base. 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, both the Tonle Sap field studies and the stakeholder consultation in the Mekong Delta indicate that the efforts to enhance local adaptation capacity should build on existing livelihoods as well as lessons learnt from the exceptional events of the past. The informants 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 adaptive capacity. Supporting and nurturing these ideas can thus be seen as one of the keys for enhancing the overall adaptation capacity as well (Nuorteva et al. 2010).

DISCUSSION

Changes and their timescales

Due to the multitude of spatial and temporal scales included in the assessment of climate change impacts, it is obvious that such impacts should be looked at together with other
environmental changes. In the Mekong, the development of large-scale hydropower dams represents undoubtedly the most important change factor to be considered together with climate change, indicating a need to assess the possible impacts of these two drivers simultaneously. While such assessment has not yet been done comprehensively, Table 1 shows some preliminary estimates by presenting a simplified summary of the expected impacts of these two changes to selected hydrological indicators in the Tonle Sap.

As can be seen from the table, the hydrological impacts of climate change and hydropower development are estimated to be largely opposite to each other. An exception to the opposing effects of changing climate and hydropower development is the dry season water level that is estimated to increase due to both hydropower development and climate change. Given the radical negative consequences that this is expected to have for the floodplain ecosystems of the Lower Mekong Basin (Kummu & Sarkkula 2008), this combined impact of increased dry season water level poses a serious concern for the Lower Mekong floodplains, and would therefore require a more detailed study.

The impacts of climate change and hydropower development are also likely to occur at noticeably different timescales, and they cannot therefore be considered simply to counter-balance each other. The most remarkable changes in climate-related variables such as precipitation and sea level rise are estimated to occur over the time span of several decades. On the other hand, the changes caused by large-scale hydropower development in terms of increasing reservoir capacities and their consequent impacts are going to be felt with much shorter timescale, possibly already over next 5–20 years.

The differences in the timescales of climate change and hydropower development are illustrated in an simplified form in Figure 3, which shows the slowly increasing trends in climatic variables over the coming decades, and compares these to the swiftly intensifying changes projected for the storage capacity of planned hydropower reservoirs already within next decade or so. While the figure does not show directly the timescale of the actual impacts of climate change and hydropower development, many of their impacts are closely related to the variables presented in the figure and they can therefore be expected to have similar timescales. As Figure 3 illustrates only the timescales within which the variables are expected to start to change, most of the impacts caused by such changes will in the long run be simultaneous—assuming that the planned hydropower dams will still be in operation in the latter half of the century. Yet, it is important to consider also the so-called intermediate period, i.e. the period within which the impacts of hydropower development are already felt, but the most severe climate change impacts are not yet.

Table 1 | A summary showing simplified, estimated impacts of hydropower development and climate change on selected hydrological indicators in the Tonle Sap area. Impact timescale refers to the time horizon within which the impacts are expected to start to occur

<table>
<thead>
<tr>
<th>Hydrological variable</th>
<th>Impact: development</th>
<th>Impact: climate</th>
<th>Certainty of climate impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average water level (Feb–Jul)</td>
<td>↑</td>
<td>↑</td>
<td>Very likely increases</td>
</tr>
<tr>
<td>Average water level (Aug–Jan)</td>
<td>↓</td>
<td>↑</td>
<td>Likely increases</td>
</tr>
<tr>
<td>Annual cumulative flooded area</td>
<td>↓</td>
<td>↑</td>
<td>Very likely increases</td>
</tr>
<tr>
<td>Maximum water level</td>
<td>↓</td>
<td>↑</td>
<td>Likely increases</td>
</tr>
<tr>
<td>Maximum flooded area</td>
<td>↓</td>
<td>↑</td>
<td>Likely increases</td>
</tr>
<tr>
<td>Flood start date</td>
<td>→</td>
<td></td>
<td>Occurs possibly later in average years and earlier in driest years</td>
</tr>
<tr>
<td>Flood peak date</td>
<td>←</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Flood end date</td>
<td>←</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood duration</td>
<td>↓</td>
<td>↑</td>
<td>Likely occurs later</td>
</tr>
<tr>
<td>IMPACT TIMESCALE</td>
<td>Short–medium (−5–30 years)</td>
<td>Medium–long (−20–100 years)</td>
<td></td>
</tr>
</tbody>
</table>

*Data on hydropower development is summarised from the modelling results of WUP-FIN Project (MRCS/WUP-FIN 2007; Kummu & Sarkkula 2008), while data on climate change is based on the research presented in this article, providing an average of all simulated climate scenarios (TKK & SEA START RC 2009; Västilä 2009; Västilä et al. 2010).
CONCLUSIONS

Climate change adaptation in the broader context of environmental and social change

This article has presented our understanding of the possible implications of climate change in the Lower Mekong Basin, concluding that remarkable impacts to the areas’ water resources, and consequently, to ecosystems and livelihoods are expected, particularly in the longer term. Due to the trans-boundary nature of the Mekong River, such impacts are to be felt through changes at multiple geographical scales, making their assessment particularly challenging. At the same time several other factors are likely to induce changes in the area, often with much shorter timescales.

There is thus a need for integrated assessment of different changes impacting water resources and environment, instead of separate assessments focusing merely on climate change or, for that matter, on hydropower development, irrigation, land use changes and so forth. To fully understand the combined impacts of these varied changes, a cumulative impact assessment should be carried out and the impacts of the different changes considered at multiple spatial scales (Kummu 2008). Due to the exceptionally long timescale of climate change impacts, it is also crucially important to consider thoroughly the temporal scales of different impacts.

The adaptive capacity is not, however, based on understanding of environmental changes alone, but also very much on people and related institutions and policies. Consequently, in addition to the environmental changes, other changes—social, economic, political, legal and institutional—have a remarkable effect on the ways the societies are able to cope with and respond to changes (Leary et al. 2008b). Climate change adaptation should thus be seen as an integral part of broader development policy, and not merely as an environmental issue—as seems still often to be the case in the Mekong countries.

Adaptation to climate change has different facets, including reducing exposure and minimising sensitivity of the vulnerable groups as well as increasing their capacity to cope with future risks. Reducing exposure is usually seen to require profound understanding of climate change impacts and a certain level of certainty about the future risks, as the measures to reduce exposure relate in most cases to costly investments such as infrastructure. Enhancing the coping capacity, on the other hand, is commonly building on softer approaches such as strengthening the resilience of households and communities to future risk as well as supporting sustainable and equal practices in the use of natural resources.

Consequently, the most feasible ways to build adaptive capacity at the local level are essentially the same as those needed for example in livelihood diversification and, more generally, in poverty reduction and sustainable development (see also Banhuri 2009; Le Blanc 2009). Enhancing climate
change adaptation should therefore build on these initiatives, and support them to respond also to the emerging impacts from climate change. Our findings indicate that in many cases the most straightforward way to increase the adaptive capacity is to support local livelihoods and enhance the living conditions of local people, and the poorest in particular. Such a finding is supported by other studies such as Resurreccion et al. (2008) and Le Blanc (2009).

In addition, there is plenty to learn from the past experiences of adaptation, leading to the recognition of successful—and failed—adaptation mechanisms and of existing knowledge gaps. Climate change adaptation planning may thus be viewed as a risk communication process that feeds information to the stakeholders and policymakers to help them to revise and articulate their adaptation strategies. Consequently, climate change forms a kind of stress test for understanding these specific characteristics is a prerequisite for the success of any community (Cutter et al. 2008). Throughout their history people have responded to changing climate produces varying impacts at different locations and the adaptive capacity makes each area vulnerable to climate change in its own way. Understanding these two fundamental preconditions is particularly crucial in most developing countries—such as Cambodia and Vietnam—where their economic, institutional and political systems. Indeed, one needs only to look back some 30 years—a relatively short period in climate change impact studies—to understand how fundamentally different both Cambodia and Vietnam were in terms of their economic, institutional and political systems.

**Area-based approach for climate change adaptation**

The national adaptation policies, including those in Cambodia and Vietnam, build largely on sectoral approaches, with different ministries and organisations considering climate change predominantly from their specific view points (see also Michel & Pandya 2009). While usually providing a natural starting point for adaptation actions, we suggest that such a sectoral view alone is inadequate to address the diverse needs related to adaptation. This is the case particularly in terms of strengthening the household resilience as well as understanding the different spatial and institutional scales involved (see also Acosta-Michlik et al. 2008; Cutter et al. 2008; Resurreccion et al. 2008).

The social-ecological system in any particular area has its own characteristics, consisting of various sectors that cannot be really separated from each other. Understanding these specific characteristics is a prerequisite for the success of any community (Cutter et al. 2008). Throughout their history people have responded to changing climate produces varying impacts at different locations and the adaptive capacity makes each area vulnerable to climate change in its own way. Understanding these two fundamental preconditions is particularly crucial in most developing countries—such as Cambodia and Vietnam—where their economic, institutional and political systems. Indeed, one needs only to look back some 30 years—a relatively short period in climate change impact studies—to understand how fundamentally different both Cambodia and Vietnam were in terms of their economic, institutional and political systems.

Area-based approach for climate change adaptation

The national adaptation policies, including those in Cambodia and Vietnam, build largely on sectoral approaches, with different ministries and organisations considering climate change predominantly from their specific view points (see also Michel & Pandya 2009). While usually providing a natural starting point for adaptation actions, we suggest that such a sectoral view alone is inadequate to address the diverse needs related to adaptation. This is the case particularly in terms of strengthening the household resilience as well as understanding the different spatial and institutional scales involved (see also Acosta-Michlik et al. 2008; Cutter et al. 2008; Resurreccion et al. 2008).

The social-ecological system in any particular area has its own characteristics, consisting of various sectors that cannot be really separated from each other. Understanding these specific characteristics is a prerequisite for the success of any community (Cutter et al. 2008). Throughout their history people have responded to changing climate produces varying impacts at different locations and the adaptive capacity makes each area vulnerable to climate change in its own way. Understanding these two fundamental preconditions is particularly crucial in most developing countries—such as Cambodia and Vietnam—where their economic, institutional and political systems. Indeed, one needs only to look back some 30 years—a relatively short period in climate change impact studies—to understand how fundamentally different both Cambodia and Vietnam were in terms of their economic, institutional and political systems.

Area-based approach for climate change adaptation

The national adaptation policies, including those in Cambodia and Vietnam, build largely on sectoral approaches, with different ministries and organisations considering climate change predominantly from their specific view points (see also Michel & Pandya 2009). While usually providing a natural starting point for adaptation actions, we suggest that such a sectoral view alone is inadequate to address the diverse needs related to adaptation. This is the case particularly in terms of strengthening the household resilience as well as understanding the different spatial and institutional scales involved (see also Acosta-Michlik et al. 2008; Cutter et al. 2008; Resurreccion et al. 2008).

The social-ecological system in any particular area has its own characteristics, consisting of various sectors that cannot be really separated from each other. Understanding these specific characteristics is a prerequisite for the success of any community (Cutter et al. 2008). Throughout their history people have responded to changing climate produces varying impacts at different locations and the adaptive capacity makes each area vulnerable to climate change in its own way. Understanding these two fundamental preconditions is particularly crucial in most developing countries—such as Cambodia and Vietnam—where their economic, institutional and political systems. Indeed, one needs only to look back some 30 years—a relatively short period in climate change impact studies—to understand how fundamentally different both Cambodia and Vietnam were in terms of their economic, institutional and political systems.
cross-sectorial actions. While such an approach will naturally have to build on existing governance structures and their limitations, we still believe that it would encourage the different sectors to work better together and bring the context-specific challenges and opportunities more into the discussion. In this way the adaptation planning also addresses better the possible trade-offs between the sectors.

To conclude, our findings indicate that climate change forms an important crosscutter and a risk multiplier for water and natural resources use in the Mekong Region. At the same time it is obvious that climate change must be viewed in the broader context within which a variety of changes are taking place at different temporal and spatial scales. This is important for four main reasons. Firstly, the amount of resources being put into climate change adaptation is likely to increase astronomically in the near future (see e.g. Banuri 2009; Copenhagen Accord 2009). The adaptation activities thus have a potential to enhance significantly our understanding of the linkages between nature and society as well as our capacity to respond to various environmental challenges. Secondly, climate change itself is expected to have remarkable—largely negative—impacts for ecosystems and society, and it will therefore impact directly the development of the region.

Thirdly, the timescale within which the most severe impacts of climate change are to be felt is exceptionally long, and the temporal dimensions of different changes require therefore particular attention, including the overlaps and gaps between their estimated impacts. Finally, current activities on climate change adaptation tend to apply a rather narrow approach, often focusing only on climate change per se. To ensure that the increasing resources for adaptation are really used to respond to the different environmental changes, the adaptation efforts should have the right kind of focus and scope from the very beginning. For this to happen, we see that the understanding of the broader environmental and socio-political context is the most critical factor.

ACKNOWLEDGEMENTS

The research presented in this article formed a part of the research project “Water and Climate Change in the Lower Mekong Basin”. The project was funded by the Ministry for Foreign Affairs of Finland with additional funding from the Maa-ja vesitekniikan tuki ry. and Academy of Finland project 111672. Thank you for the two anonymous reviewers for comments that considerably improved the text. In addition, thank you very much to our colleagues and project counterparts in Cambodia, Vietnam and elsewhere for your cooperation and support. Special thanks to Dr Tin Ponlok, Sour Sethy, Dr Babette Resurreccion, Dr Juha Sarkkula, Jorma Koponen and Professor Pertti Vakkilainen.

REFERENCES


EEA 2007 Climate Change and Water Adaptation Issues. European Environment Agency (EEA), Copenhagen, Denmark.


Kääkönen, M. 2008 Mekong Delta at the crossroads: more control or adaptation? Ambio 37 (3), 205–212.


MONRE, MOIT, Peoples Provincial Committee of Quang Nam, Peoples Provincial Committee of Ben Tre & Ministry of Foreign Affairs, Denmark, Danida 2005 Overview of the Hydrology of the Mekong Basin. Mekong River Commission (MRC), Phnom Penh, Cambodia.


MRC 2005 Overview of the Hydrology of the Mekong Basin. Mekong River Commission (MRC), Vientiane, Lao PDR.


Nuorteva, P. 2009 Resilience and Adaptation Strategies of Rural Livelihoods in Tonle Sap Area, Cambodia. Master’s Thesis, Department of Geography, University of Helsinki, Finland.


SEA START RC & WWF 2008 Climate Change impacts in Krabi Province, Thailand—A study of environmental, social, and economic challenges. Southeast Asia START Regional Center and WWF Greater Mekong Programme.


The Socialist Republic of Vietnam 2008 Decision on approval of the National Target Program to respond to climate change. Unofficial Translation of Vietnamese Version, Hanoi, Vietnam.

Group, Helsinki University of Technology (TKK), and Southeast Asia START Regional Center (SEA START RC), Chulalongkorn University, Water & Development Publications, Helsinki University of Technology, Espoo, Finland.

TKK & SEA START RC 2009 Water and Climate Change in the Lower Mekong Basin: Diagnosis & recommendations for adaptation. Water and Development Research Group, Helsinki University of Technology (TKK), and Southeast Asia START Regional Center (SEA START RC), Chulalongkorn University, Water & Development Publications, Helsinki University of Technology, Espoo, Finland.


World Resources Institute in collaboration with United Nations Development Programme, United Nations Environment Programme & World Bank 2008 World resources 2008: Roots of resilience—growing the wealth of the poor. World Resources Institute (WRI), Washington, DC, USA.


First received 15 July 2009; accepted in revised form 14 January 2010