Water & Development Research Group

Tonle Sap now and in the future?

Final Report of the Exploring Tonle Sap Futures study

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Cover photo: 'Tonle Sap boats' by Marko Keskinen

We welcome comments on our report: Marko Keskinen and Matti Kummu (@aalto.fi). www.wdrg.fi

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FOREWORD

The Tonle Sap Lake and its floodplains form vital resource for the entire Cambodia. Unique flood pulse system and huge fish productivity have been driving the development of the surrounding societies at least since the Angkorian era in 9th Century. Today, the lake-floodplain system is a global biodiversity hotspot that supports remarkable production of fish, rice and other agricultural and wetland products. The Tonle Sap forms the basis for the food security and livelihoods for millions of Cambodians.

People living in and around the Tonle Sap Lake have adapted to the enormous annual variation of the lake's water level: many even live in floating houses on the lake itself. People's livelihoods are closely connected to the lake and natural resources it enables and supports. While agriculture remains the main source of livelihood, the role of fishing and related activities is remarkable as well. The urban centers around the lake have rather different livelihood structures, with growing involvement in trade, service sector, construction, and industrial activities. Tourism forms increasingly important source of income as well, and ecotourism to visit the natural wonder of the Tonle Sap Lake is also growing.

The Tonle Sap Lake is closely connected to the mighty Mekong River, making the management of the Tonle Sap also a transboundary issue. The annual floods of the Mekong are the main driving force for the Tonle Sap flood pulse, extending the lake to the vast floodplains and bringing fertile suspended solids as well as fish larvae to the lake-floodplain system. Without the Mekong, the Tonle Sap would not be as productive and unique as it is today. For the same reason, the environmental changes happening in the Mekong River Basin have direct impacts to the Tonle Sap system.

The regional 'Exploring Mekong Region Futures' project and the related 'Exploring Tonle Sap Futures' study seek to increase the understanding of the future development of the Tonle Sap area. The fundamental element of the study was a set of scenario workshops held around the Tonle Sap. The workshops were organised by Tonle Sap Authority (TSA) in collaboration with Supreme National Economic Council, CSIRO and Aalto University, and they were participated by number of experts from different line agencies and organisations. We would like to thank all workshop participants for their valuable contributions that also help to shape the conclusions and policy recommendations presented in this report. We would also like to express our sincere thanks to the Tonle Sap Authority for their invaluable support for the Tonle Sap study and the entire 'Exploring Mekong Region Futures' project.

The findings from the 'Exploring Tonle Sap Futures' study –presented in this Final Report– emphasise the major environmental impacts that the Mekong hydropower development and climate change are expected to cause to the Tonle Sap system. At the same time, the report highlights the key socio-economic and livelihood trends in the area, noting the remarkable potential that the large cohorts of young people bring to the development of the area. Together, these environmental, social and economic trends are likely to change the future of the Tonle Sap area dramatically. Our analysis shows that such a change can result in both positive and negative livelihood outcomes, depending largely on what kind of policies are implemented at national and provincial as well as local levels.

We hope that our research facilitates and encourages discussion on the future of the Tonle Sap area: please do share your ideas, questions and critique!

Exploring Tonle Sap Futures study team

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INTRODUCTION TO THE STUDY

The **Exploring Tonle Sap Futures study** (http://bit.ly/YifGN5) represents one of the five local case studies of the 'Exploring Mekong Region Futures' project (http://bit.ly/Mc9geV), led by The Commonwealth Scientific and Industrial Research Organisation (CSIRO). The Exploring Tonle Sap Futures study focuses on the Cambodia's Tonle Sap Lake area. The study is implemented by a consortium consisting of Aalto University, 100Gen Ltd., Hatfield Consultants Partnership and Institute of Technology of Cambodia, complemented with work by EIA Ltd. and VU University Amsterdam. The partners of the Tonle Sap study are the **Tonle Sap Authority (TSA)** and the Supreme National Economic Council (SNEC).

The Mekong Futures project looks at water-energy-food-climate nexus at different levels. The project's aim is to improve community livelihoods and well-being in the Mekong Region through combined quantitative and qualitative research that informs decisions and investments for the sustainable production, distribution, and use of energy, food and water. To ensure this, the regional project conducted a series of futures workshops at both regional and local scales, providing a systematic, participatory framework to reveal and refine local development scenarios (Smajgl et al 2011).

The Exploring Tonle Sap Futures study described in this Final Report focuses on the interactions between livelihoods and the Tonle Sap's flood pulse within a broader context of water-energy-food-climate nexus. Majority of the Tonle Sap livelihoods are dependent on the Tonle Sap's terrestrial and aquatic environment, and any changes in Tonle Sap's water resources and its land cover are therefore likely to influence the status of local livelihoods. Hydropower development in the Mekong River is a key factor in any future development of the Tonle Sap, largely due to the likely negative impacts that hydropower development would have for the Tonle Sap flood pulse and, in particular, the immense fish production of the lake.

A central part of the Exploring Tonle Sap Futures study is **two Research Components focusing on water resources and livelihoods.** The main aim of the Research Component on water ('Hydrological analysis') is to model the possible impacts of changes to the Tonle Sap flood pulse that drives the aquatic ecosystem productivity. The Research Component on livelihoods ('Livelihood analysis') aims to analyse current livelihood setting and trends –and, more broadly, social and economic trends– in the Tonle Sap area, building on spatial analysis of two governmental Population Census available for the area. The database analysis was complemented by CSIRO-led household survey (CSIRO 2011, Ward & Poutsma 2013), which provided more detailed view on livelihoods diversity and potential changes. For more information on Research Components and their methodology and key findings, see Baseline Report of our study (Keskinen et al. 2011).

This Final Report aims to do two three things. First, it summarises the main findings from the two Research Components, including both the current status and possible future changes and trends related to water and livelihoods (Parts 1 & 2). Second, through four alternative futures, the report aims to link our research on water and livelihoods together by presenting possible consequences of water- and livelihood-related changes in the Tonle Sap area by year 2040 i.e. within next 30 years (Part 3). Finally, we provide conclusions as well as policy recommendations on the way forward (Part 4). **The findings are thus presented under four parts as follows:** Part 1: Tonle Sap now, Part 2: Changing Tonle Sap, Part 3: Tonle Sap in 2040 – four alternative futures, and Part 4: Conclusions.

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PART 1: TONLE SAP NOW

WATER

- The foundation for the current Tonle Sap lake-floodplain system is **flood pulse**, caused by the lake's close connection with the Mekong River. Flood pulse drives the high aquatic productivity of the lake, enabling immense fish production. It also explains to large extent the ecosystem conditions and habitats in the floodplain.
- Tonle Sap flood pulse has **two critical dimensions: water flow & nutrients**.
  Water flow determines the key characteristics of the flood pulse, including its timing, amplitude, extent etc. Water flow thus defines the water level and extent of flooding in the Tonle Sap.
- Nutrients refer to the suspended sediments flowing from the Mekong to the lake, bringing a major nutrient boost that is a key driver for the aquatic production and also helps agriculture in the floodplains.

PEOPLE

- In 2008, there were **1'707'000 people living** in the Tonle Sap area as defined in this study (see Page 11). There are 1555 villages, with a great majority (1244) being rural. Demographically remarkable is the dominance of the youth: as of today, the two biggest age groups are between 15-19 years and 20-24 years.
  This **'youth surge'** is thus just entering the work force, changing dependency ratio.
- According to Population Census 2008, the main livelihood sector in the area is very clearly **agriculture**, with 61% of total work force having it as main livelihood. Trade comes second (11.5%) and fishing third (4.5%). Yet, the role of **fishing** is actually much more significant as it provides many with an additional source of livelihood and income. The CSIRO Tonle Sap Household Survey indicates similar figures, although the proportions of trade (around 20%) and fishing (5.8%) are higher than in Census. Together, agriculture and fishing are the major contributors for **national food security**.
- In terms of livelihoods, the Tonle Sap area can be defined as three distinct zones: **Zone 1** (5% of population living closest to the lake + having fishing as main livelihood), **Zone 2** (60% of population further in the floodplain, involved mainly in agriculture) and **Zone 3 i.e. Urban Zone** (35% of the population). The livelihood profiles of the zones are very different, although all zones see also lively interactions between each other.
- There are **major differences within each three zones and even within each of the 18 sub-zones**. In general, Zone 1 ('Lower Floodplain') is in the most disadvantageous situation, while Urban Zone is least dependent on natural resources.
  Zone 2 ('Upper Floodplain') has clearly the greatest amount of people.

Unique hydrology: Tonle Sap flood pulse

The Tonle Sap Lake and its floodplains are known for the extraordinary flood pulse[1] system, which is closely connected to –and dominated by– the Mekong River[2]. The lake is connected to the Mekong through the 120 km long Tonle Sap River, with the confluence of the two rivers occurring in the Cambodian capital Phnom Penh. During the southwest monsoon, the water level in the Mekong River rises faster than that in the lake, and as a result part of the Mekong floodwaters run upstream to the Tonle Sap River. The Mekong flow causes the entire Tonle Sap River to reverse its flow back towards the Tonle Sap Lake, which is a hydrological phenomenon globally unique for a river of this size (MRCS/WUP-FIN 2007; Kummu & Sarkkula 2008; MRC 2010; Mak et al. 2012).

As a result, the only outlet of the Tonle Sap Lake is impeded, and the flood waters extend to large floodplain areas surrounding the lake: the average surface area of the lake rises from around 3'000 km^2 during the dry season to a maximum of up to 14'500 km^2 (MRC 2005; MRCS/WUP-FIN 2007). The variation in the lake's water level is equally large, ranging from less than two metres during the dry season to over 10 metres during the wet season (MRC 2005; MRCS/WUP-FIN 2007; Mak et al 2012). The Mekong floods affect both water quantity and water quality in the Tonle Sap Lake. The suspended sediment flux from the Mekong to the Tonle Sap is massive[3], and provides a major nutrient boost for the lake-floodplain system, including fisheries.

The Tonle Sap is thus a very exceptional lake, as the impacts of any environmental change –whether due to climate change, hydropower development or other drivers– are felt as a combination of changes in its own basin (e.g. hydropower development and irrigation structures in Tonle Sap floodplain: see Annex J) and that of the Mekong River (e.g. e.g. large-scale hydropower development in the Mekong mainstream and tributaries by several Mekong countries, including Cambodia). The actual 'impact basin' of the Tonle Sap Lake is thus not merely the lake basin (86'000 km^2), but the entire Mekong River Basin upstream from the Tonle Sap (680'000 km^2). This, naturally, makes the assessment of potential impacts to the area a particular challenge, and also makes the management of the lake area very much a regional issue as well (Keskinen et al. 2010, 2011). All in all, the Tonle Sap Basin includes 12 main secondary basins plus a surface water area of the lake (Annex B).

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[1] Ecosystems that experience fluctuations between terrestrial and aquatic states, such as the Tonle Sap ecosystem, are called pulsing ecosystems, and the hydrology of such systems can be described as a 'flood pulse' (Kummu et al. 2006). Organisms of the two phases exchange energy and nutrients: the terrestrial organisms use the stranded aquatic material and the nutrients released by the aquatic organisms during decomposition (Kummu et al. 2006). Likewise, energy and nutrients become accessible for the aquatic organisms when terrestrial habitats are flooded and large amounts of inorganic and organic matter of the terrestrial phase are transferred into the water body (Lamberts 2008, MRC/IKMP 2010).

[2] Out of the total average inflow to the Tonle Sap Lake (79.0 km^3), more than half (57%) originates from the Mekong River either as inflow through the Tonle Sap River (52%) or as overland flow (5%), with the share of the Tonle Sap's own tributaries being around 30% and that of precipitation some 13% (MRCS/WUP-FIN 2007).

[3] The average annual suspended sediment flux into the Tonle Sap system from the Mekong is some 5.1 million tonnes/year, with the lake's tributaries contributing an additional 2.0 million tonnes/year. As the annual outflow of the sediments from the lake back to Mekong is around 1.4 million tonnes/year, it is estimated that around 80% of the sediment the Tonle Sap system receives from the Mekong River and tributaries –meaning 5.7 million tonnes per year– is stored in the lake system: majority of this sediment is deposited in the floodplain, not in the lake proper (MRC/IKMP 2010).

The flood pulse is a major driving force for the productivity of the Tonle Sap ecosystem, including the immense fish production of the lake system (Kummu et al. 2006; MRCS/WUP-FIN 2007; Lamberts 2008; MRC/IKMP 2010; Mak et al. 2012). In addition, the suspended solids flux from the Mekong to the Tonle Sap provides an important nutrient boost –particularly phosphorus[4]– for the aquatic productivity as well as for the terrestrial habitats in the Tonle Sap floodplains: the sediment flux is thus a positive thing for the aquatic production of the lake, including fisheries (MRC/IKMP 2010). The tall gallery forest stripe surrounding the permanent lake constitutes an important ecosystem and also critical physical barrier between the open lake and the floodplain, creating favourable conditions for sedimentation within the forested zone (Kummu & Sarkkula 2008). In general, the flood pulse has a major influence on the ecosystem conditions and habitats in the floodplain, and it has therefore also partly defined the land use patterns –including the location of agricultural fields– in the floodplain (Arias et al. 2012).

The Tonle Sap flood pulse has therefore two interlinked characters: quantitative (water levels, including the timing and duration of the different phases of flood pulse), and qualitative (water quality, including the suspended solids flux). While the characteristics of the annual flood pulse differ, the seasonal variation of the Tonle Sap's water volume and level is generally regular (Lamberts 2006, MRCS/WUP-FIN 2007, MRC/IKMP 2010). Figure 1 below presents some of the key hydrological characteristics of the Tonle Sap flood pulse, including the seasonal water level and the rapidity of its changes as well as the variation in flood timing between different years. For more detailed information, see e.g. MRCS/WUP-FIN (2003, 2007) as well as Mak et al. (2012).

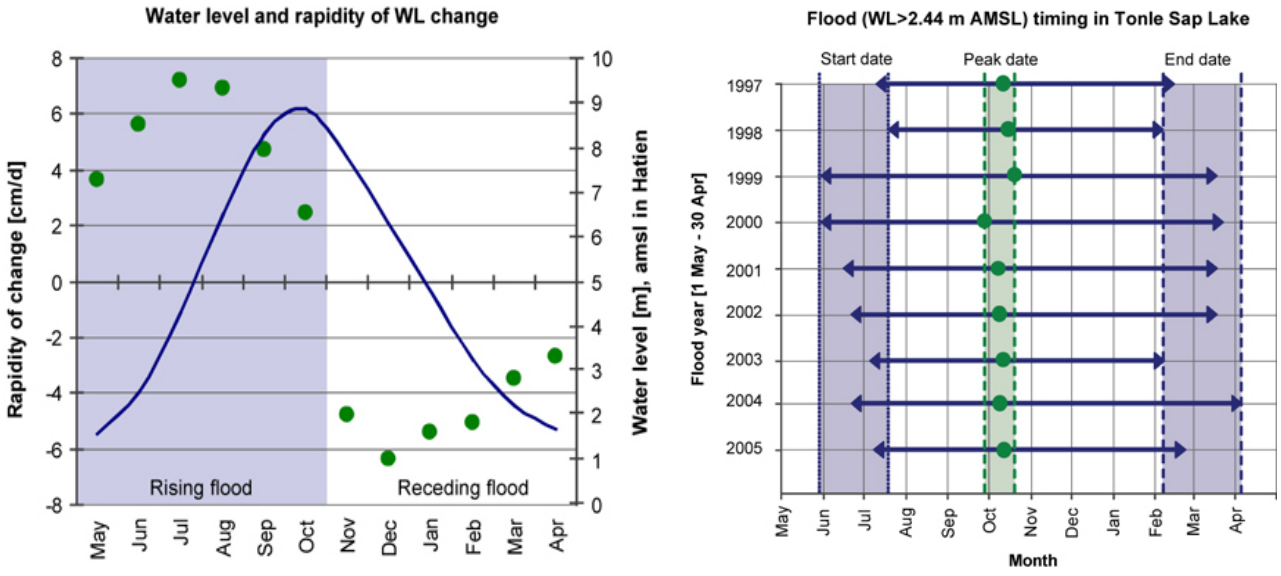


Figure 1. Tonle Sap flood pulse characteristics. Average water level (WL) and rapidity of WL change (left); and flood timing (right). Source: Kummu & Sarkkula (2008).

[4] The water samples taken by MRC/IKMP (2010) indicate that the Mekong's flood waters entering the Tonle Sap system have constant levels of bioavailable phosphorus in the bound to the sediment particles, with values varying between 31 - 42% of the total phosphorus. The sediment particles are thus carrying an important part of biologically available phosphorus to the Tonle Sap, in addition to the orthophosphate dissolved in the water.

The critical role of fisheries

Due to the flood pulse system, the Tonle Sap's fish production has been significant already for centuries, creating the foundation for local livelihoods, food security and daily nutrition. It is estimated that there are around 300 different fish species in the Tonle Sap system, including almost hundred migratory species (Mak et al. 2012; Ziv et al. 2012).

While the proportion of fishing as the main occupation can be considered relatively small (4.5% of workforce in the Tonle Sap area, meaning around 40'000 people), fishing forms also critical secondary and tertiary activities. Fishing thus acts as an important complementary livelihood activity for people whose main livelihood source is non-fishing, usually agriculture. In addition, numerous people generate their livelihood from fishing-related industries, such as fish processing and trade. It must also be noted that the radical fishing lot reform –announced by Prime Minister Hun Sen in April 2012– has removed majority of the remaining private fishing lots in the country, releasing the lot areas as public fishing grounds (MRC 2012). This is naturally a major change in fisheries management in the Tonle Sap, and it can considerably increase the role of fisheries in the area both in terms of livelihoods and income.

The Royal Government of Cambodia's recent National Strategic Development Plan Update estimates that more than 4.5 million people –in other words around one third (33%) of the total population– are directly involved in fishery sector (RCG 2010). Not surprisingly, the report concludes that (RCG 2010: 37): "*Fish continues to be a vital source of food, nutrition and income of millions of Cambodians."* Indeed, besides direct livelihood benefits, fish forms a critical component of national food security. Up to 80% of all animal protein consumption in Cambodia comes from fish and other aquatic animals (Hortle 2007; RGC 2010; IFReDI 2012). This is a proportion that is considerably higher than in most countries of the world, making Cambodia particularly dependent on its fisheries: fish is clearly the most important source of animal protein in the country. In addition, thanks to active fish migration and fish export, Cambodian fisheries contributes also considerably for regional food security (e.g. Chea & McKenney 2003; Baran 2005; Ziv et al. 2012).

Fish and fish-related livelihoods are thus socially and economically very important for Cambodia and the entire Mekong Region (van Zalinge et al. 2000; Baran 2005; EIC 2007; Chadwick et al. 2008; MRC 2010). Establishing the total economic value of fish catches –or even the amount of fish catch itself– is complicated by a lack of reliable, long-term data[5]. In addition, the exclusion of the subsistence fish catch from most monetary estimates is likely to lead to substantial underestimations (van Zalinge et al. 2000). According to the most recent estimates by IFReDI (2012) Cambodia's annual inland fish catch is around 570'000 tons, rising to 625'000 tons when other aquatic animals are included. Such estimate is bit bigger but in the same range than most previous catch estimates (e.g. van Zalinge et al. 2000; MRC 2009a; RGC 2010). Estimating the economic value of this fish catch is difficult and for example the exclusion of the subsistence fish catch from most monetary

[5] Due to the lack of reliable, long-term data, the estimates on fish and fisheries in the Mekong Region remain sketchy and most probably hugely under-reported, and the reliability of fisheries statistics can be questioned in many areas, including the Tonle Sap Lake (e.g. Lamberts 2006). The role of fisheries in supporting the economy and the livelihoods has also been frequently downplayed in the national and regional development plans, particularly in those related to hydropower development (Friend et al. 2009).

estimates leads easily to substantial underestimations (van Zalinge et al. 2000). Yet, the economic value at landing site is estimated to be somewhere around US$150 and US$200 million per year (van Zalinge et al. 2000). This value is believed to increase in the processing and marketing chain up to US$600 million (van Zalinge et al. 2000; EIC 2007; MRC 2009a).

Due to large amount of migratory fish species and the Tonle Sap's critical role as the 'fish growing factory' of the Mekong, the Tonle Sap system is crucial also for the fisheries of the entire Mekong River system. The Mekong's fisheries is one of the most abundant freshwater fisheries in the world, with hundreds of fish species and approximately 2.6 million tonnes harvested annually from the Lower Mekong Basin alone (Poulsen et al. 2004; Sverdrup-Jensen 2002; Coates et al. 2003; Hortle 2007; MRC 2010; Ziv et al. 2012). The economic value of the Mekong fisheries is equally remarkable, with the current estimates of the first-sale value being between US$ 2.2 billion and US$ 3.9 billion per year, and between US$4.3 and US$7.8 billion in retail markets (Dugan et al. 2010).

Socio-economic setting

As of March 2008 (the enumeration date of Population Census 2008, carried out by the National Institute of Statistics and covering all households in entire Cambodia) around 1.7 million people were living in the 1'555 villages of the Tonle Sap Lake and floodplains area, as defined in this study (Figure 2). Out of these people, some 51.3% were female (Annex F). The average population growth from 1998 and 2008 was 14%, and the annual average was thus around 1.4%. Yet, the differences within the Tonle Sap area are extensive, with the fastest population growth occurring in urban areas and particularly in Siem Reap: this is due to both population growth and migration.

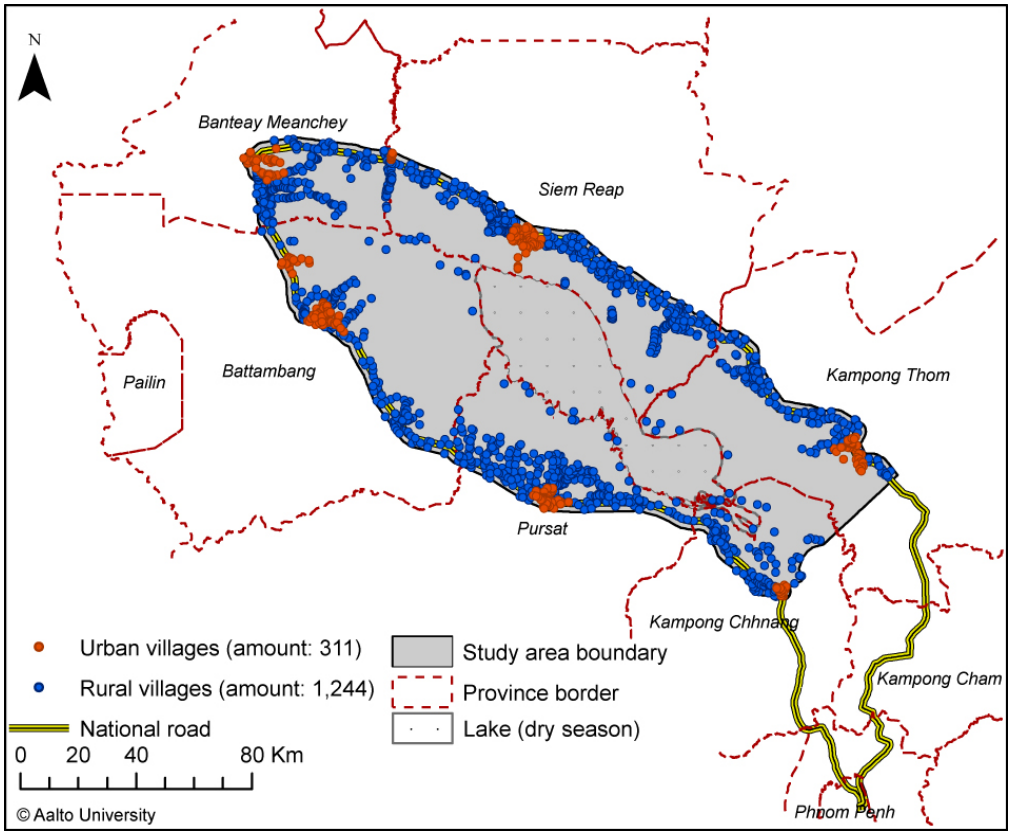


Figure 2. Villages within the study area used in this study: rural villages in blue and urban villages in red.

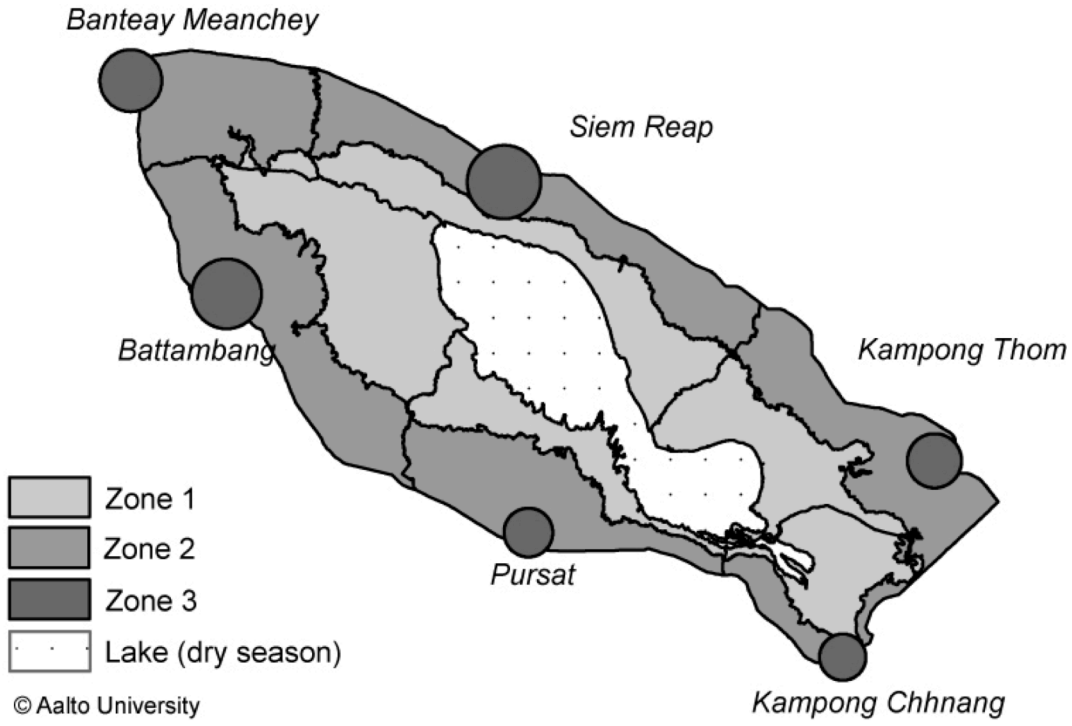


Figure 3. The zones used in this study, including three main zones (1 = Lower Floodplain, 2 = Upper Floodplain and 3 = Urban) + related 18 sub-zones forming the province-specific resource use zones.

The Tonle Sap area is in this study defined to be the area between National Roads 5 and 6, with a 3-kilometer buffer beyond the roads (to include households and villages on both sides of the road). The area doesn't include the Tonle Sap River, as the area is separated from the river with a line located east from Kampong Chhnang and Kampong Thom (Figure 2).

The area was divided into three distinct zones: Zone 1 (5% of population), Zone 2 (60%) and Zone 3 (35%) (Figure 3). **Based on their location in the floodplain and main livelihood activity these zones can also be called 'Lower Floodplain Zone' or 'Fishing Zone' (Zone 1), 'Upper Floodplain Zone' or 'Agricultural Zone' (Zone 2) and 'Urban Zone' (Zone 3).** The division into different zones is originally based on the topographic location and urbanisation (Keskinen & Rath 2002; Keskinen 2003, 2006), but during this study we confirmed that the zones are also statistically distinct from each other when using Census data (Salmivaara 2012; Salmivaara et al. 2013).

It is very important to note that while we call the two rural zones (Zone 1 & 2) also according to their most important livelihood activity (fishing and agriculture, respectively), it does not mean that there would be no fishing activities outside so-called Fishing Zone, or that people living in this Zone would only fish. On the contrary: as can be seen from Table 2, there are people involved in e.g. fishing and agriculture in all three zones. **The 'nicknames' of the two rural zones are thus only indicative of their main livelihood activity, and help thus to distinguish between the zones.**

There are several other ways to define and study the Tonle Sap area as well. Government agencies such as TSA use also so-called **Tonle Sap 'protection zones'** that provide boundaries for the differing possibilities of natural resources use (Annex A). It is difficult to get information on the exact boundaries of these protection zones, but at general level the Tonle Sap floodplain is divided into three protection zones as follows:

- **Protection Zone 1:** villages and farmlands along National Roads 5 and 6
- **Protection Zone 2:** buffer area between Protection Zones 1 and 3, including farmland and shrublands where farmers used to grow floating rice: now becoming receding rice fields.
- **Protection Zone 3:** flooded forest, grassland and wetland areas around the Tonle Sap Lake, covering an area of around 640,000 ha.

The **Tonle Sap Sub-area analysis done for the CNMC** takes then a broader, basin-wide view on the Tonle Sap. The analysis looks at the entire Tonle Sap Basin i.e. MRC Sub-area 9C, including 12 main secondary basins as well as the lake area (Annex B). The CNMC's Tonle Sap report uses Commune Database 2008 for its analysis: according to the analysis results the total population in the Tonle Sap Basin is 4'858'548 people (Annex C; Mak et al. 2012). The information derived from the Commune Database includes several interesting socio-economic indicators for the Tonle Sap Basin, including dependency ratio (70%), proportion of poor population (31.1%) and access to education (67.2%). There are, however, major differences between the different major river basins of the Tonle Sap area: for more, see Annex C.

Cambodia's population growth has slowed down within the last decade, and is currently less than was anticipated earlier. In 2002 Cambodia's annual population growth was estimated to be around 2.5% (World Bank 2002), while the National Institute of Statistics (NIS) estimated that the population of Cambodia is likely to increase from 13.1 million in 2001 up to 20.3 million in 2021, indicating an average annual growth rate of 2.2% (NIS 2000). For the Tonle Sap Region, the rate was estimated to be even higher, 2.4% (NIS 2000; Keskinen 2003). Yet, according to the most recent Population Census 2008, the population growth for all of Cambodia was 1.5% (NIS 2008), while UNFPA estimates that in 2011 it was 1.2% per year (UNFPA 2011). The Commune Database 2008 figures for the Tonle Sap indicate that annual population growth in the basin was on average 1.3% in 2008, with remarkable regional differences ranging from 0.2% in Stung Chinit basin to 3.5% in Siem Reap basin (Mak et al. 2012).

The 2008 age structure in the Tonle Sap –consistent with rest of Cambodia– is relatively young, with the largest age groups being those between 10-14 years (214'400 people) and 15-19 years (217'800 people) i.e. people who were born mainly in the 1990s (Figure 4). Consequently, as of today, the biggest age groups are estimated to be those between 15-19 years and 20-24 years. This 'youth surge' is now entering the work force: while it can be seen as a major challenge, it also presents an enormous possibility for the development of the area (for more, see Part 2). Similar age structure is visible also in other studies, such as CNMC's Tonle Sap Sub-area report (Mak et al. 2012).

A great majority of the people (~90%) in the Tonle Sap area live in the verges of the floodplain close to the National Roads 5 and 6 (Figure 2). In general, people living closer to the National Roads are in many ways in a better situation than the ones living closest to the Tonle Sap Lake. The people living close to the lake are generally poorer, less educated, have fewer livelihood options, do not own agricultural land and depend strongly on common property resources such as water bodies and flooded forests for their livelihood (Keskinen 2003, 2006; Nuorteva 2009; Keskinen et al. 2011). Also ethnic issues are important in the areas closest to the lake, as many of the floating villages are inhabited by ethnic Vietnamese whose status remains unclear.

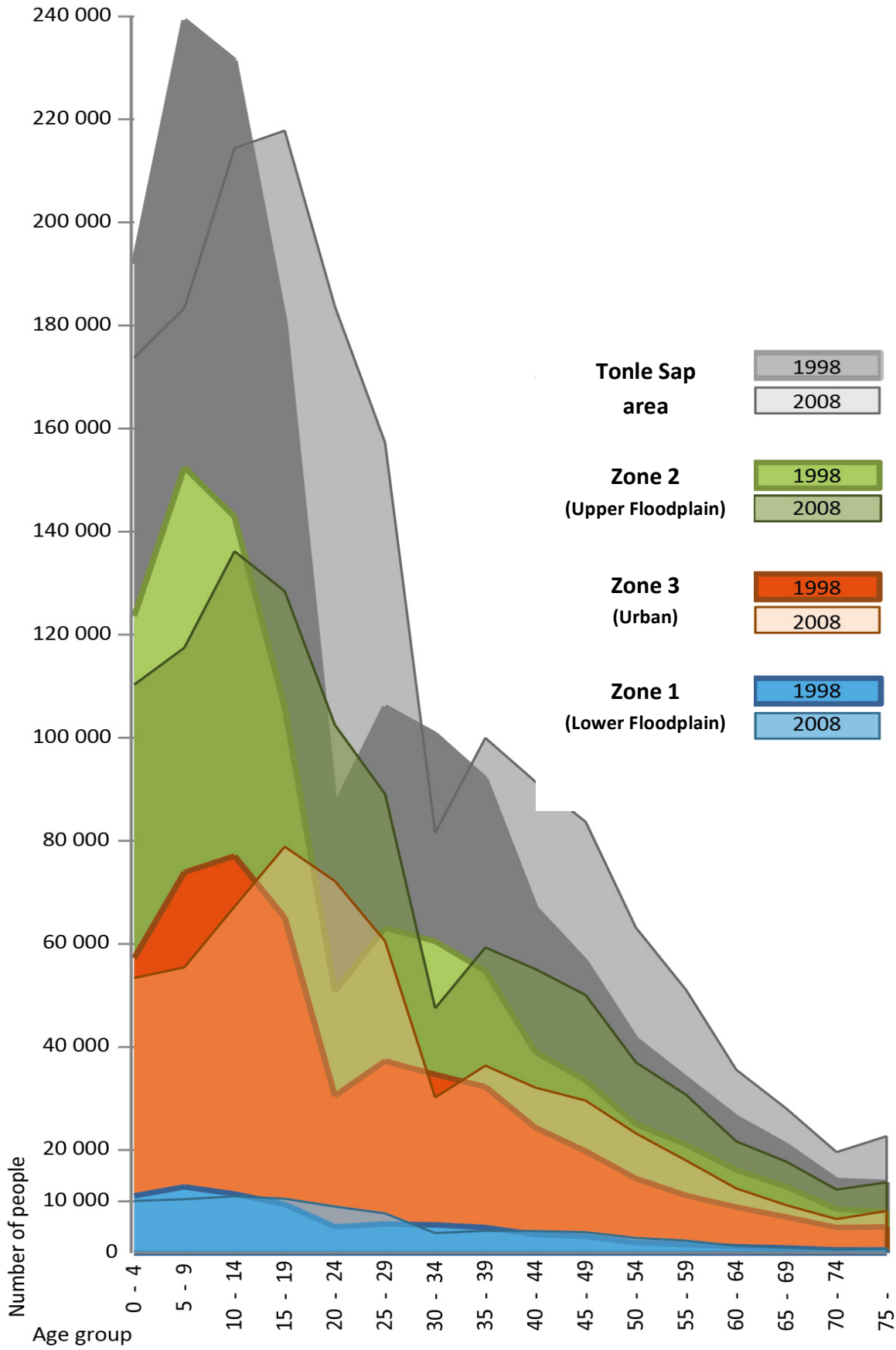


Figure 4. Age profiles according to five-year age groups for the entire Tonle Sap area as well as for each of the three zones separately. Data from Population Census 1998 and 2008.

Table 1. Summary table of our database analysis by zones and sub-zones: general socio-economic indicators. Data from Population Census 2008.

	General socio-economic and demographic indicators							
	Villages	Population	Economic active population (EAP)	Household (HH) size	Dependency ratio	% of adult population (+15) literate	% HHs with 1 or more mobile phone	% HHs with 1 or more boat
Zone 1 (Lower Floodplain)	**86**	**84 491**	**45 089**	**5.1**	**68.30**	**64.5**	**29.5**	**78.6**
Banteay Meanchey	3	2 323	1 222	5.3	85.30	76.5	20.8	90.5
Battambang	10	14 681	6 232	5.3	69.54	63.4	27.7	88.3
Kampong Chhnang	20	21 634	11 982	5.1	72.02	62.2	26.1	86.5
Kampong Thom	11	8 958	5 184	5.1	61.15	49.9	38.9	86.4
Pursat	18	14 964	8 501	5.0	68.27	64.5	25.0	67.5
Siem Riep	24	21 931	11 968	5.1	65.87	71.9	33.2	71.4
Zone 2 (Upper Floodplain)	**1158**	**1 028 971**	**541 832**	**4.8**	**66.63**	**76.6**	**28.0**	**10.0**
Banteay Meanchey	180	140 101	72 245	4.8	71.20	79.0	29.4	17.0
Battambang	155	239 157	118 908	4.8	66.55	79.2	31.4	7.3
Kampong Chhnang	102	79 794	43 639	4.4	64.80	81.5	23.7	7.8
Kampong Thom	150	133 515	69 886	4.8	72.06	68.2	22.7	16.7
Pursat	271	176 951	95 788	4.7	64.99	77.7	22.3	7.2
Siem Riep	300	259 453	141 366	4.9	63.34	75.4	34.6	7.0
Zone 3 (Urban)	**311**	**593 626**	**279 148**	**4.9**	**55.11**	**83.8**	**58.5**	**5.7**
Banteay Meanchey	44	79 328	38 822	4.8	57.74	86.5	55.0	12.1
Battambang	85	186 155	82 807	4.9	54.12	84.5	58.2	1.2
Kampong Chhnang	24	40 127	20 041	4.9	51.62	85.8	64.6	15.6
Kampong Thom	39	54 015	25 941	4.6	57.14	83.4	53.6	9.4
Pursat	46	42 185	20 474	4.6	54.47	85.4	53.1	0.5
Siem Riep	73	191 816	244 397	5.1	55.13	80.2	64.8	5.2
Total for Tonle Sap	**1555**	**1 707 088**	**866 069**	**4.8**	**64.42**	**77.4**	**34.2**	**12.9**

***Note**: The proportions for socio-economic and demographic indicators are calculated as averages from the village level proportions,* and they are thus likely to be bit different to the actual proprtions at sub-zone level.

Livelihoods: close connection with water

The livelihood setting of the Tonle Sap area is as exceptional as its flood pulsing system. While people living in the lake and its floodplains have adapted to the seasonal variation of the lake's water level, they are also deeply dependent on the resources and services that the lake and its floodplains provide, including agricultural products as well as fish and other aquatic animals and plants (Evans et al 2004; Keskinen 2006; Chhun 2010; Hall & Bouapao 2010; MRC 2010; Mak et al. 2012). Many people also engage in several different livelihood activities, depending also on the season. The Tonle Sap flood pulse thus forms a major driving force also for the area's livelihoods.

Table 2. Summary table of our database analysis for key industry sectors i.e. livelihood sectors. For selected data on change + visualisations, see Annex D and Annex E. Data from Population Census 2008.

	Involvement in six key industry / livelihoods sectors													
	Agriculture (incl. Forestry)		Fishing		Wholesale		Construction		Transport, storage & communication		Manu-facturing		Total for six key livelihood sectors	
	%	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%	Amount
Zone 1 (Lower Floodplain)	**28.3**	**12 589**	**60.2**	**26 801**	**6.7**	**2 998**	**0.2**	**103**	**1.3**	**568**	**0.9**	**408**	**97.6**	**43 467**
Banteay Meanchey	97.4	1 190	0.4	5	0.3	4	0.0	0	0.0	0	0.2	2	98.3	1 201
Battambang	2.4	145	85.6	5 253	7.7	472	0.4	24	0.8	51	0.6	34	97.4	5 979
Kampong Chhnang	43.7	5 212	43.2	5 161	7.3	873	0.4	43	2.2	267	0.8	90	97.6	11 646
Kampong Thom	17.3	887	76.8	3 935	3.8	195	0.0	0	0.0	2	0.3	15	98.3	5 034
Pursat	21.4	1 756	67.5	5 533	7.1	579	0.1	5	1.1	92	1.1	90	98.3	8 055
Siem Riep	28.5	3 399	58.1	6 914	7.3	875	0.3	31	1.3	156	1.5	177	97.0	11 552
Zone 2 (Upper Floodplain)	**80.9**	**433 777**	**1.3**	**6 898**	**5.6**	**30 253**	**2.5**	**13 246**	**1.5**	**8 095**	**2.1**	**11 253**	**93.9**	**503 522**
Banteay Meanchey	81.9	58 794	0.5	374	4.6	3 323	2.0	1 449	1.7	1 212	2.7	1 912	93.4	67 064
Battambang	76.6	90 193	1.5	1 789	7.2	8 422	3.4	4 043	2.2	2 594	2.4	2 845	93.3	109 886
Kampong Chhnang	81.3	35 404	2.2	956	4.9	2 114	1.1	464	1.1	478	3.1	1 341	93.6	40 757
Kampong Thom	85.7	59 329	1.2	834	4.5	3 104	1.0	660	1.3	896	1.7	1 159	95.3	65 982
Pursat	84.8	79 451	1.4	1 278	5.0	4 646	1.0	951	1.1	1 053	1.1	1 049	94.4	88 428
Siem Riep	79.0	110 606	1.2	1 667	6.2	8 644	4.1	5 679	1.3	1 862	2.1	2 947	93.9	131 405
Zone 3 (Urban)	**27.6**	**74 411**	**1.7**	**4 549**	**24.0**	**64 677**	**6.8**	**18 275**	**7.8**	**21 043**	**6.3**	**16 917**	**74.1**	**199 872**
Banteay Meanchey	32.9	12 667	0.6	213	27.0	10 391	6.9	2 658	7.6	2 910	6.6	2 540	81.6	31 379
Battambang	30.3	24 180	0.7	530	24.1	19 256	6.5	5 217	7.5	6 008	7.6	6 046	76.6	61 237
Kampong Chhnang	18.3	3 644	12.0	2 381	27.7	5 502	4.0	804	7.9	1 562	9.5	1 897	79.5	15 790
Kampong Thom	53.6	13 701	0.7	177	15.7	4 014	2.6	661	4.5	1 156	3.7	944	80.8	20 653
Pursat	38.4	7 547	0.3	57	20.3	3 995	4.8	940	5.5	1 084	4.6	897	73.9	14 520
Siem Riep	53.2	126 677	4.1	9 772	13.0	31 038	5.8	13 705	4.3	10 341	3.2	7 726	83.7	199 259
Total for Tonle Sap	**61.3**	**520 777**	**4.5**	**38 248**	**11.5**	**97 928**	**3.7**	**31 624**	**3.5**	**29 706**	**3.4**	**28 578**	**87.8**	**746 861**

***Note**: The amount for different livelihood sectors indicate the amount of people whose main livelihood activity is the one indicated.*
% for different livelihood sectors indicate the proportion of livelihood from the economic active population (EAP) in the zone/sub-zone.

According to the Population Census 2008, the six biggest 'livelihood sectors'[6] in Tonle Sap in 2008 were agriculture (61% of total work force), wholesale and retail trade (11.5%), fishing (4.5%),

[6] In Census, these are referred to as 'Industry sectors', but as they represent livelihood sources in general, we call them 'livelihood sectors'. It should be noted that while many people are involved in several livelihood activities, we are here referring to their most important livelihood source only.

construction (3.7%), transport, storage & communication (3.5%) and manufacturing (3.4%) (Table 2). Agriculture thus remains as the area's main livelihood source (Annex D), while fishing remains an important source of livelihood in the villages close to the lake (Annex E). In addition, wholesale and retail trade is an important livelihood source in all three zones and in the Urban Zone in particular.

In terms of main livelihood sources, there are clear differences between the different areas in the lake-floodplain (Figure 5). According to the Population Census 2008, fishing forms the main source of livelihood (60%) in the areas closest to the lake: the area is thus called also the 'Fishing Zone' or 'Lower Floodplain Zone' in this study. Rice cultivation and other agricultural activities are the most important source of livelihood in other rural areas, and the area is thus called the 'Agricultural Zone' or 'Upper Floodplain Zone'. Secondary occupations –including fishing– form an important supplement for the main livelihood activities, particularly during the dry season when the involvement in the main occupation is less intensive. In urban areas (the six provincial capitals and few bigger district towns, called the 'Urban Zone') the livelihood sources are much more diverse, and their dependency on natural resources and the Tonle Sap is less.

It should be noted, however, that the three livelihood zones used in this study differ greatly in terms of the amount of people: a great majority of the people (~1 million) lives in 1'158 villages of Zone 2 (Upper Floodplain), while around a third of the people (~600'000) lives in the 311 villages of the Urban Zone. The Zone 1 (Lower Floodplain) is the smallest, with some 5% (~85'000) of the total population living in the Tonle Sap area (Figure 9). The three livelihood zones were further divided into 18 sub-zones, based on the administrative boundaries of the six Tonle Sap provinces: there are also remarkable differences between these sub-zones (see e.g. Annex D, Annex E).

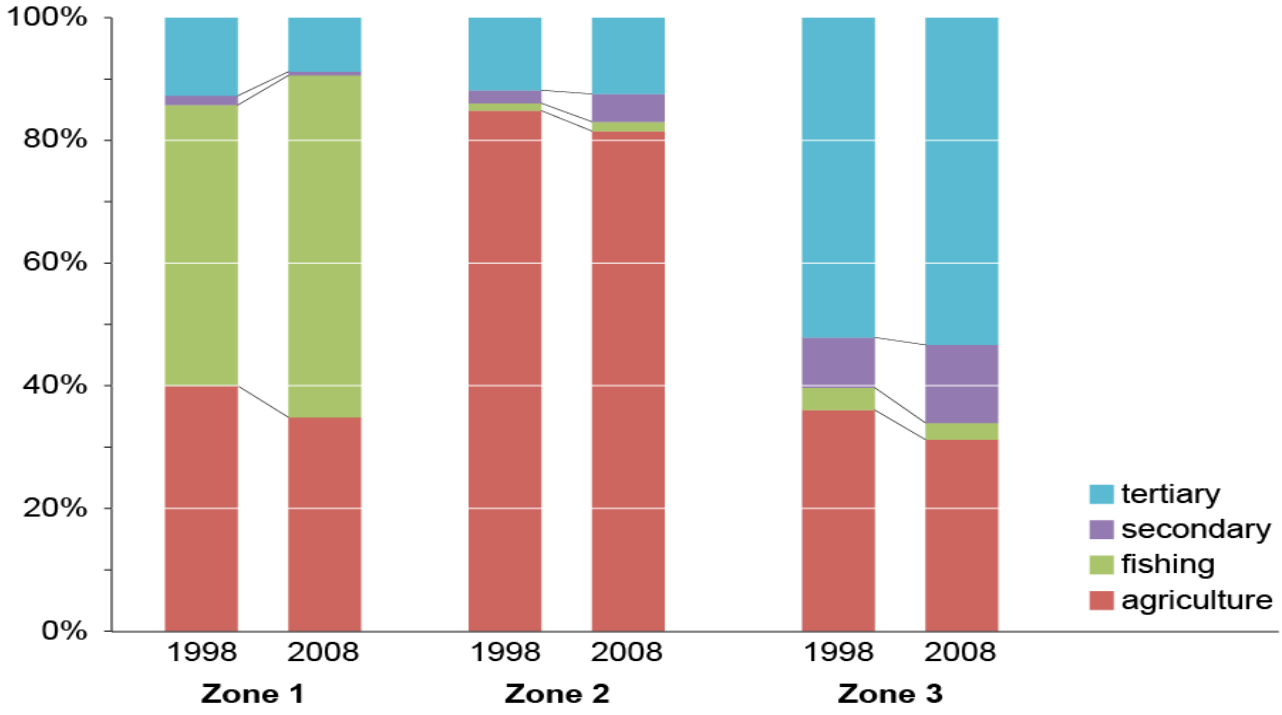


Figure 5. The main livelihood sources in different zones in 1998 and 2008. Primary sectors include fishing and agriculture (incl. hunting and forestry); secondary sectors manufacturing, mining, construction, water and electricity supply; and tertiary sectors rest of the industry sectors such as service, trade, transport. Data from Population Census 1998 and 2008.

Similar livelihood structures have been reported by other household surveys and participatory studies carried out in the area (see e.g. Keskinen 2003, 2006; Nuorteva 2009; Chhun 2010; Hall & Bouapao 2010; Nuorteva et al. 2010). The results from the **CSIRO Tonle Sap Household Survey 2011**[7] indicate a similar general livelihood structure as well. According to the survey, more than 60% of the respondent households have agriculture i.e. growing rice, vegetables or maize and other cereals as their main livelihood activity[8] (Table 3). Consistent with the Census data, trade forms the second most important livelihood activity, but with a larger proportion than reported in the Census: 18.5% of the people were found to be involved in family business and an additional 5% working in other services such as shops. In addition, some 1.1% were involved in food processing or sale of fish. Fishing is the third most important source of livelihood with around 6% of all the people in the Tonle Sap having it as the main livelihood source (Table 3). The role of fishing was, however, much greater in the Zone 1 (Lower Floodplain), where approximately 60% of respondents were involved in fishing and related activities (aquaculture, processing, sale).

Table 3. The main livelihood activities in different zones, based on the data of the CSIRO Tonle Sap Household Survey 2011. Livelihood activities include both production activities (agriculture, fishing etc.) and cash activities (labour, wages and other direct cash income). 'Other activities combined' includes several smaller activities, such as livestock, handicrafts, remittance and plantation work[9]*.*

MAIN LIVELIHOOD ACTIVITY (CSIRO Tonle Sap Household Survey 2011)	**Zone 1 (Lower Floodplain)**	**Zone 2 (Upper Floodplain)**	**Zone 3 (Urban)**	**TOTAL for three zones**
	%	%	%	%
Number of households responding	***80*** *(8.5%)*	***717*** *(76.2%)*	***144*** *(15.3%)*	***941***
Growing rice	**6.3**	**68.5**	**29.2**	**57.2**
Growing maize and cereals	**17.5**	**0.6**	**0.0**	**1.9**
Growing vegetables	**1.3**	**0.1**	**2.8**	**0.6**
Fishing	**56.3**	**1.4**	**0.0**	**5.8**
Aquaculture	**1.3**	**0.0**	**0.0**	**0.1**
Food processing or sale of fish	**2.5**	**0.8**	**1.4**	**1.1**
Family business other	**10.0**	**16.3**	**34.0**	**18.5**
Working in other services (shop etc.)	**2.5**	**3.6**	**15.3**	**5.3**
Construction related activities	**0.0**	**2.8**	**5.6**	**3.0**
Farm labour	**0.0**	**0.6**	**0.0**	**0.4**
Government employee	**2.5**	**2.6**	**6.9**	**3.3**
Other activities combined	**0.0**	**2.6**	**4.9**	**2.8**

[7] The CSIRO Tonle Sap Household Survey 2011 was carried out by CSIRO as part of the Exploring Mekong Region Futures project in 50 villages comprising 1000 household interviews. A majority i.e. 71.6% of the households interviewed were from the Zone 2 (Upper Floodplain), with 14% from the Urban Zone and 8% from the Zone 1 (Lower Floodplain). Out of 50 surveyed villages, three villages i.e. 60 households were outside the Tonle Sap area as defined in this study: they were left out from the analysis presented here.

[8] Respondents were asked to define what was from their different livelihood activities the most important one for their household.

[9] Note: as Zone 2 (Upper Floodplain) represent clearly the largest proportion of the household survey sample, the values of Zone 2 bias upwards the total proportion for three zones: this holds for other tables related to CSIRO Tonle Sap Household Survey as well.

The results from the CSIRO Tonle Sap Household Survey 2011 also include information about other livelihood sources, including production activities such as agriculture and fishing by season as well as cash activities that consist of direct cash payments such as labour and wages (CSIRO 2011; Ward & Poutsma 2013). The results from the analysis of these categories emphasise the diversity of livelihoods in the area, showing that several households have more than one livelihood source to secure their income and food security (Table 4). In addition, the production activities often differ between wet and dry season. Yet, none of the households listed more than three production activities per season, with 3.4% of the households having three wet season production activities and only 1% of the households having three dry season production activities. Similarly, none of the households listed more than three cash activities.

The CSIRO Tonle Sap Household Survey results indicate that the involvement in fishing is clearly greatest in the Zone 1 (Lower Floodplain), with 84% of household fishing in the wet season and 53% in the dry season (Ward & Poutsma 2013). In the Zone 2 (Upper Floodplain), 14% of the households were involved in fishing in the wet season and 9% in the dry season. In general, the households in the Zone 1 (Lower Floodplain) seem to depend strongly on production activities –in other words, on natural resources– for their income, with only around half of the people involved in any kind of cash activity. In the Zone 2 (Upper Floodplain) three out of four households were involved in cash activities, while in Urban Zone this proportion is over 90% (Table 4). On the other hand only half of the households in the Urban Zone are involved in wet season production activities, and less than 25% in dry season production activities (Ward & Poutsma 2013), suggesting less direct dependency on natural resources. These findings are also largely in line with the results from the analysis of the Population Census data.

Table 4. The amount of different production activities and cash activities among the households in different zones. Table based on the data from CSIRO Tonle Sap Household Survey 2011. See also Footnote 7.

AMOUNT OF PRODUCTION AND CASH ACTIVITIES (CSIRO Tonle Sap Household Survey)	**Zone 1 (Lower Floodplain)**	**Zone 2 (Upper Floodplain)**	**Zone 3 (Urban)**	**TOTAL for three zones**
Number of households responding	***80*** *(8.5%)*	***717*** *(76.2%)*	***144*** *(15.3%)*	***941***
One wet season activity	**82.5%**	**82.4%**	**50.0%**	**83.5%**
Two wet season activities	**10.0%**	**26.2%**	**9.7%**	**24.5%**
Three wet season activities	**1.3%**	**3.8%**	**1.4%**	**3.4%**
One dry season activity	**85.0%**	**45.9%**	**23.6%**	**48.8%**
Two dry season activities	**28.8%**	**7.8%**	**1.4%**	**8.8%**
Three dry season activities	**5.0%**	**0.6%**	**0.7%**	**1.0%**
One cash activity	**52.5%**	**76.4%**	**91.7%**	**80.2%**
Two cash activities	**18.8%**	**25.2%**	**50.7%**	**29.3%**
Three cash activities	**6.3%**	**5.0%**	**13.2%**	**6.4%**

The livelihood-related information from the CNMC's Tonle Sap Sub-area Report (Mak et al. 2012) provides a bit broader view, as it is based on the household-level data from Commune Database 2008 and includes 956'296 households from the entire Tonle Sap Basin (Mak et al. 2012). As a result, the proportions of different occupations within the entire Tonle Sap Basin also look bit different. According to the information derived from the **Commune Database 2008** for the CNMC's Tonle Sap Sub-area Analysis report (Mak et al. 2012), rice cultivation is clearly the most important occupation in the Tonle Sap Basin (73.2%), followed by cash crop farming (6.3%), government service (5.8%), private sector involvement (5.5%), traders (3.7%) and other service providers (3.6%). The role of agriculture as households' primary occupation is thus around 81% (rice + cash crop + fruit tree + vegetable), in other words clearly greater than what was indicated by Census data or CSIRO Tonle Sap Household Survey results. As the CNMC's analysis included data from the entire Tonle Sap Basin (including upland areas), the proportion of fishing as primary occupation in the entire Tonle Sap Basin is at 1.9% considerably low, but on the other hand its proportion in the Tonle Sap lake area is at 75% even more than in our analysis (Mak et al. 2012; Annex C). In addition, it is very likely that much bigger proportion of people have fishing as secondary or tertiary occupation in the entire basin as well.

PART 2: CHANGING TONLE SAP

WATER

- The Tonle Sap lake-floodplain system is impacted from changes occurring in both Tonle Sap's own catchment (86'000 km^2) and that of the Mekong River upstream from Phnom Penh (680'000 km^2). **The close connection to the Mekong makes the Tonle Sap particularly vulnerable to changes, whether by dams or climate change.**
- Within the timeframe of this study (years 2032-2042), **Mekong hydropower development has clearly stronger impact to flood pulse, impacting both nutrients and water flows.** Climate change brings increasing uncertainty to the estimates: often even the direction of the change caused differs depending on the GCM used.
- Cumulative impacts of climate change and hydropower operation will **significantly impact the Tonle Sap flood pulse**, leading to delayed, shorter, and smaller flood and higher dry season water level. In addition, the dams are estimated to significantly reduce the inflow of nutrient-rich sediments to the Tonle Sap system.
- The changes in water flows alter flood pulse dynamics, leading to significant reduction in floodplain area and sediment inflow. Together, they are likely to cause changes in floodplain habitats and to **impact negatively ecosystem productivity, including fish.**

PEOPLE

- The population growth in the Tonle Sap is still relatively rapid, although slowing down. Cities and their surrounding areas experience particularly rapid population increase due to population growth and migration. **Urban areas are the 'engines of change'** in the area in many ways. Yet, most people in rural areas seem **not be willing to migrate**.
- **'Youth surge'** represents a major influence on the development of the area, but it can also lead to problems if the new work force is not able to engage in meaningful job opportunities. Related to this, education, infrastructure, markets and private sector development will have an important influence on the development trajectories.
- General **levels of education remain low**, although improvements are being observed.
- **Agriculture dominates** the livelihood activities, although the proportion is slowly decreasing. Yet, population growth means that the total number of people in the agricultural sector increased by 130'000 people between 1998-2008. There are also remarkable differences in livelihood development between different sub-zones. **Fishing remains important** both as a livelihood option and food security provider.
- Involvement in several **smaller sectors** such as construction, manufacturing and services has grown rapidly between 1998 and 2008, suggesting increasing livelihood diversification particularly in urban and semi-urban areas.

Changes in flood pulse, floodplain habitats & fish

As part of this study, we assessed the possible changes in Tonle Sap flood pulse due to two major drivers: Mekong hydropower development and climate change[10]. We analysed the impact of these two key drivers both separately and together, using a ten-year timeframe until the year 2042. This is to our knowledge the first time that the cumulative impacts of hydropower development and climate change on the Tonle Sap flood pulse have been assessed at this level of detail. For more information, see the Baseline Report (Keskinen et al. 2011) and Lauri *et al.* (2012).

The unique flood pulse of the Tonle Sap is likely to change in the future, with the planned hydropower dam development in the Mekong River Basin (both mainstream and tributaries) causing dramatic changes on the flood dynamics. The hydropower operation, based on our simulations, will flatten the hydrograph by causing higher dry season water levels and lower flood peaks (see Annex H). It should be noted, however, that the Mekong mainstream and tributary dams are likely to have quite differing impacts, with biggest flow changes coming from tributary dams as well as Chinese mainstream dams (as they include considerable reservoirs, unlike the planned Lower Mekong mainstream dams).

At the same time climate change is expected to cause changes to the rainfall and temperature in the area (Lauri et al. 2012), impacting the runoff and water levels in the Mekong mainstream and, thus, the Tonle Sap system. Yet, our analysis indicates that the exact impact of climate change remains unclear, mainly due to differences in the different General Circulation Models (GCMs) applied to the Mekong Region (Lauri et al. 2012) and whole monsoon Asia (Ashfaq et al. 2009). Even the direction of the change caused by climate change differs depending on the emission scenario and GCMs used (see Annex H). Consequently, it is impossible to say even whether climate change will increase or decrease the flood season water level or flood volume (Lauri et al. 2012). For this reason, we present in this chapter the impacts of climate change through envelopes of change, and not as one estimate (as is the case for hydropower development).

[10] The reservoir data for existing, under construction and planned dams were obtained from the MRC hydropower database for the Lower Mekong Basin (MRC 2009b) and complemented in China by data available from ADB (2004). In addition, some reservoirs were omitted, namely: those with active storage of less than $2x10^6$ m^3; re-regulating dams; and the Don Sahong dam that captures only part of the flow of the main river. This resulted in a database of 126 reservoirs. Climate change assessment used two IPCC scenarios (A1b and B1) and five different GCMs that proved to perform well in the Mekong region within the baseline period, all downscaled to the Mekong Region. This resulted in ten 'climate change model runs': temperature and precipitation of different model runs for the years 2032-2042 was then compared to the baseline data for the years 1982-1992. For more, see Lauri *et al.* (2012). There are naturally also local development in the Tonle Sap floodplain e.g. in the form of irrigation development, but these were not included in this analysis. For more information on our methods, see Baseline Report (Keskinen et al. 2011).

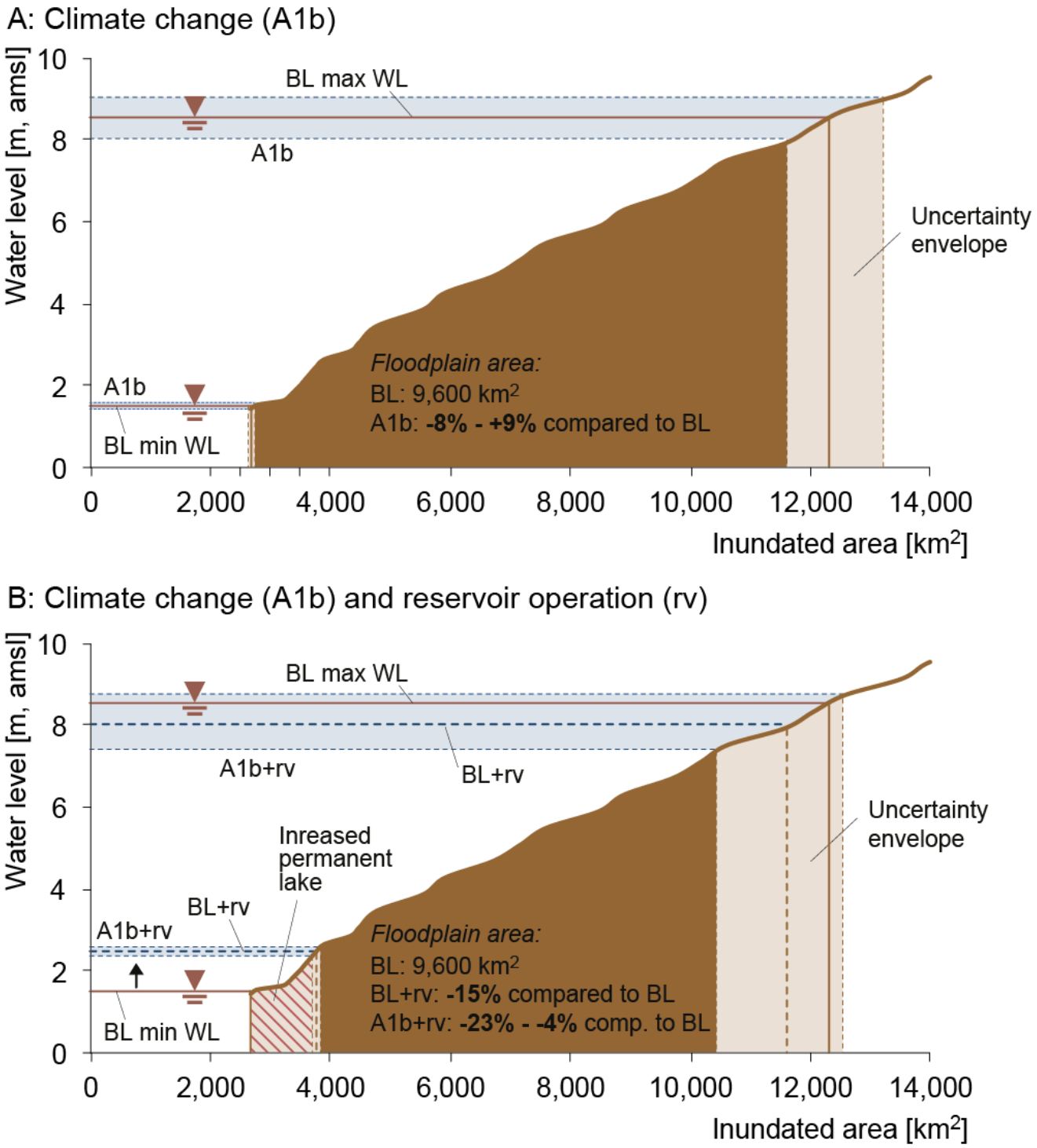


Figure 6. Impacts caused in the area of the Tonle Sap floodplain due to flow changes. Baseline (1982-1992) compared to scenario time period (2032-2042). A. Impacts caused by climate change (A1b emission scenario); and B: Impacts caused by both climate change (A1b) and hydropower development (rv). Note: uncertainty envelope refers to the variation between five GCMs (General Circulation Model) downscaled to the Mekong.

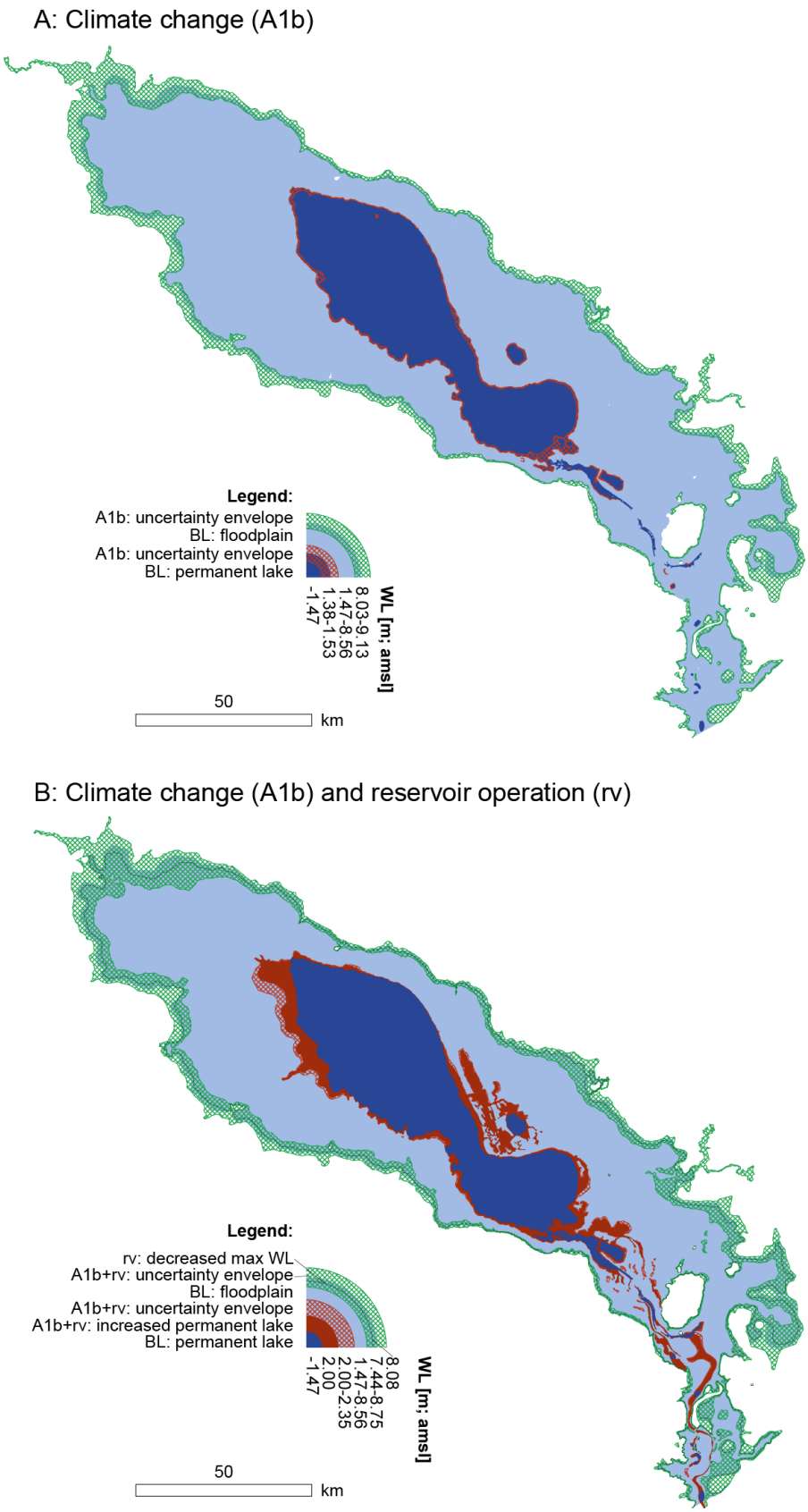


Figure 7. Maps of the future changes (2032-2042) in permanent lake and flooded areas compared to baseline (BL; 1982-1992). A: Impact of climate change (A1b emission scenario) on water levels; and B: Cumulative impacts of climate change (A1b) and reservoir operation (rv). Note: uncertainty envelope refers to the variation between five GCMs (General Circulation Model) downscaled to the Mekong.

Our analysis shows that within the timeframe of this study, climate change alone (i.e. without hydropower development) does not have a considerable impact on the dry season water level in the lake (Annex H-A; Figure 6A; Figure 7A). For the flood peak the direction of climate change impact is unclear, as stated above. The climate change impact on the flooded area (that is an important factor for ecosystem productivity) is thus very uncertain, with the estimates for the future floodplain area varying from 92% (8,832 km^2) to 109% (10,464 km^2) of the current average floodplain area of 9,600 km^2.

In contrast, the cumulative impacts of hydropower operation and climate change have a clear impact on dry season water levels, which are estimated to be 0.5-0.9 m above the current levels (Annex H-B). This would mean that the permanent lake area would increase 18-31%, submerging important habitats of, for example, flooded forest (Figure 7B). For the flood season water levels the cumulative impacts are significant, with modelling estimates indicating lower flood peaks, although with large uncertainty (Annex H-B; Figure 6B) due to the differences in GCMs used in the study. The floodplain area can reduce significantly due to cumulative impacts from climate change and hydropower reservoirs, with minimum area being around 75% of the current floodplain area (Figure 6B).

To enhance the linkage between hydrological analysis and livelihood analysis, we also calculated how hydropower operation (reservoirs) and climate change is likely to change the floodplain area in different zones and sub-zones as defined in this study (see Figure 3). The results from this analysis are summarised in Table 5. Please note that the total floodplain area in the table is bit different to the areas discussed above, since the modelled floodplain areas (e.g. Figure 6) include also some floodplain along the Tonle Sap River i.e. outside the six provinces of our study area.

As can be seen from Table 5, there are quite dramatic differences in the ranges of change of the floodplain areas within different sub-zones. When looking at the sub-zones in Upper Floodplain (Zone 2), for example, it can be noted that the cumulative impacts from hydropower reservoirs and climate change are estimated to reduce the floodplain area in the sub-zone 2 of Banteay Meanchey even by 77%, but only by 21% in the sub-zone 2 of Kampong Chhnang. On the other hand, climate change alone is estimated to increase the floodplain area for example in the sub-zone 2 of Banteay Meanchey up to 72% and of Battambang up to 43%, but only by 11% in the sub-zone 2 of Kampong Chhnang. Such major differences are naturally linked with the differing (topographic) location of the different sub-zones (Figure 3). Yet, the differences in the changes of the floodplain area are likely to result in divergent livelihood and socio-economic impacts in different sub-zones, as for example floodplain habitats in different sub-zones are likely to be differently impacted by hydropower reservoirs and/or climate change (see below).

Table 5. The estimated changes in the floodplain area of the sub-zones of Zone 1 (Lower Floodplain) and Zone 2 (Upper Floodplain) due to hydropower operation (reservoirs), climate change, and cumulatively (reservoirs + climate change). As the Zone 3 is outside the floodplain area, it was left out from the analysis. The total floodplain area for Zones 1 and 2 (8187 km^2) is smaller than the total floodplain area discussed above (e.g. Figure 6), as the latter includes also some floodplains outside the six provinces of our study area.

	Current situation (BL)	BL + reservoirs		BL + climate change (A1)				BL + reservoirs and climate change (A1)			
				Minimum area		Maximum area		Minimum area		Maximum area	
	km2	km2	change (%)	km2	change (%)	km2	change (%)	km2	change (%)	km2	change (%)
Zone 1 (Lower Floodplain)	**5 928**	**5 229**	**-12%**	**5 917**	**-0.2%**	**5 939**	**0.2%**	**5 176**	**-13%**	**5 346**	**-10%**
Banteay Meanchey	87	87	0.0%	87	0.0%	87	0.0%	87	0.0%	87	0.0%
Battambang	1 849	1 655	-11%	1 847	-0.1%	1 850	0.0%	1 633	-12%	1 704	-8%
Kampong Chhnang	739	649	-12%	737	-0.3%	743	0.5%	640	-13%	668	-10%
Kampong Thom	1 077	915	-15%	1 075	-0.2%	1 080	0.3%	908	-16%	930	-14%
Pursat	829	736	-11%	828	-0.1%	829	0.1%	728	-12%	755	-9%
Siem Reap	1 347	1 187	-12%	1 343	-0.3%	1 350	0.2%	1 180	-12%	1 203	-11%
Zone 2 (Upper Floodplain)	**2 260**	**1 852**	**-18%**	**1 813**	**-20%**	**3 184**	**41%**	**924**	**-59%**	**2 844**	**26%**
Banteay Meanchey	338	252	-25%	243	-28%	581	72%	78	-77%	521	54%
Battambang	551	438	-21%	426	-23%	791	43%	218	-60%	704	28%
Kampong Chhnang	150	136	-9%	137	-8%	166	11%	118	-21%	154	3%
Kampong Thom	497	432	-13%	425	-14%	685	38%	204	-59%	614	23%
Pursat	274	225	-18%	219	-20%	382	40%	117	-57%	336	23%
Siem Reap	449	369	-18%	361	-20%	579	29%	189	-58%	516	15%
Total for Zones 1 & 2	**8 187**	**7 081**	**-14%**	**7 729**	**-6%**	**9 123**	**11%**	**6 100**	**-25%**	**8 190**	**0.04%**

The changes in water level and floodplain area are likely to lead also to changes in the floodplain habitats. Arias et al. (2012) identify five clearly distinguishable **habitat groups** for the Tonle Sap floodplain, based on flood regime, physiognomic patterns and human activity. The five habitat groups and their main characteristics and modelled areas[11] are (Arias et al. 2012):

1) **Open water** (flooded on average for 12 months per year: modelled area 2550 km^2)
2) **Gallery forest** (flooded on average for 9 months: modelled area 657 km^2)
3) **Seasonally flooded habitats** (flooded for 5-8 months and dominated by shrublands and grasslands: modelled area 4787 km^2)
4) **Transitional habitats** (flooded for 1-5 months and dominated by (abandoned) agricultural fields, receding rice/floating rice and lowland grasslands: modelled area 4744 km^2)
5) **Rainfed habitats** (flooded up to 1 month and dominated by wet season rice fields and village crops: modelled area 8386 km^2)

Arias et al. (2012) conclude that flooding is the primary driver for general spatial distribution of the floodplain habitats in the Tonle Sap. They also modelled the potential changes in floodplain habitats due to Mekong hydropower development and climate change, concluding –similarly to our analysis– that hydropower has clearly stronger impact to potential shifts in floodplain habitats than climate change. According to Arias et al. (2012), hydropower development is likely to reduce the

[11] Arias et al. (2012) modelled the areas of the habitat groups based on the flood duration rules they created for the habitats. The modelled areas were in general on rather good agreement with the area derived from the land use maps based on JICA (1999).

spatial extent of seasonally flooded habitats and gallery forest, while favouring rainfed habitats –dominated by rice fields and village crops– in the upper parts of the floodplain. While these changes can thus lead to potential increase for the agricultural area, the reduction in the area of forests and shrublands would be a major loss for the ecosystem productivity due to the critical role that forests and shrubs have in sediment deposition, nutrient cycling, periphyton growth, primary production as well as in fish food and refuge (Arias et al 2012).

We complemented the floodplain habitat analysis with the **land type and ownership analysis**, using the data from Cambodian Socio-Economic Survey (CSES) from 2004 and 2007 (Heikinheimo 2011). In sum, our CSES analysis indicates that the most common type of land plots in Tonle Sap was wet-season land, accounting for around 80% of the lands owned by rural households and some 70% of the land areas owned by urban households. The analysis also shows that the area under irrigation –although still rather modest– has been increasing: e.g. wet-season irrigation increased in three years (2004-2007) by 11% in the land areas owned by rural households and by 9% in the land areas owned by urban households (Figure 8).

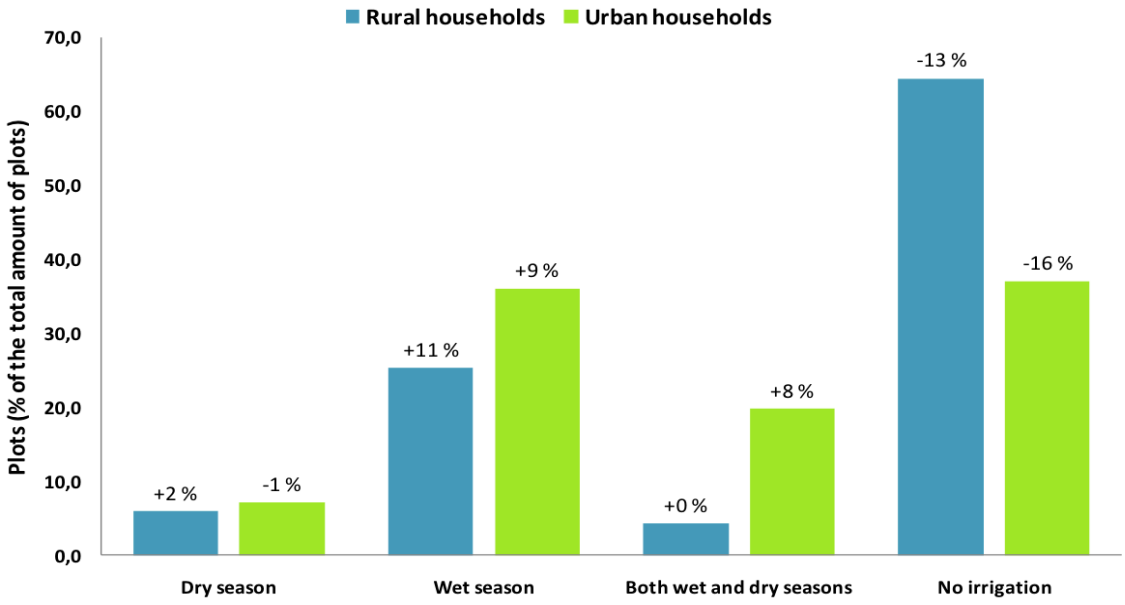


Figure 8. Data on the number of the irrigated land plots in the Tonle Sap: bars indicate the total number of plots (y-axis), while the numbers indicate the change from 2004 to 2007. Note: data does not indicate the land area, but the number of plots. Data based on Cambodian Socio-Economic Surveys 2004 and 2007.

The CSES analysis also shows that the land ownership in Tonle Sap's rural areas decreased slightly: from 83.6% of the households in 2004 to 81.0% of the households in 2007. During the same period, however, the average area of land owned by rural households increased from 1.9 hectares to 2.6 hectares. In the urban areas, the land ownership grew from 44.8% in 2004 to 45.2% in 2007, and the average area of land owned per household grew slightly as well, from 1.7 hectares to 1.8 hectares. In these figures there were also remarkable differences between the provinces: the increase of the average area of land owned per household took place in few provinces (Banteay Meanchey and Battambang), in other provinces it decreased. For more information, see Heikinheimo (2011) as well as the Annex D of our Baseline Report (Keskinen et al. 2011).

Changes in water-dependent resources, particularly fish

In terms of livelihoods and food security, the key question is how the changes in flood pulse will impact water-dependent resources and livelihoods such as fisheries, wetlands and agriculture. Due to the critical role of Tonle Sap fisheries for the entire Cambodia as well as their potential vulnerability to flow changes, we focus in this chapter particularly on fish.

Hydropower development's impacts to fish can be divided into two main categories: 1) so-called barrier effect of dams on fish migration; and 2) the impact that hydropower development has on water flows (quantity and quality), and, consequently, on e.g. fish habitats (e.g. Halls & Kshatriya 2009; Sarkkula et al. 2009; IFReDI 2012; Ziv et al. 2012). In this chapter we discuss the impacts caused by flow changes and, consequently, to Tonle Sap flood pulse: for more information on the barrier effect on fish migration, see e.g. Dugan (2008), Halls & Kshatriya (2009, Dugan et al. (2010) and Ziv et al. (2012).

While the connection between flood pulse and aquatic production is a very critical question for the Tonle Sap fisheries, providing reliable and concise answers for the Tonle Sap area remains a challenge. Due to complex interconnections between flood pulse and different (aquatic) plants and animals in the Tonle Sap system, there simply is not enough information available to reliably describe the actual dependency of these kinds of resources to the flood pulse and its diverse characteristics. Some studies have, however, been able to come up with some general conclusions on the impact range that Tonle Sap primary productivity –and, through it, fisheries– would feel due to changes in flood pulse.

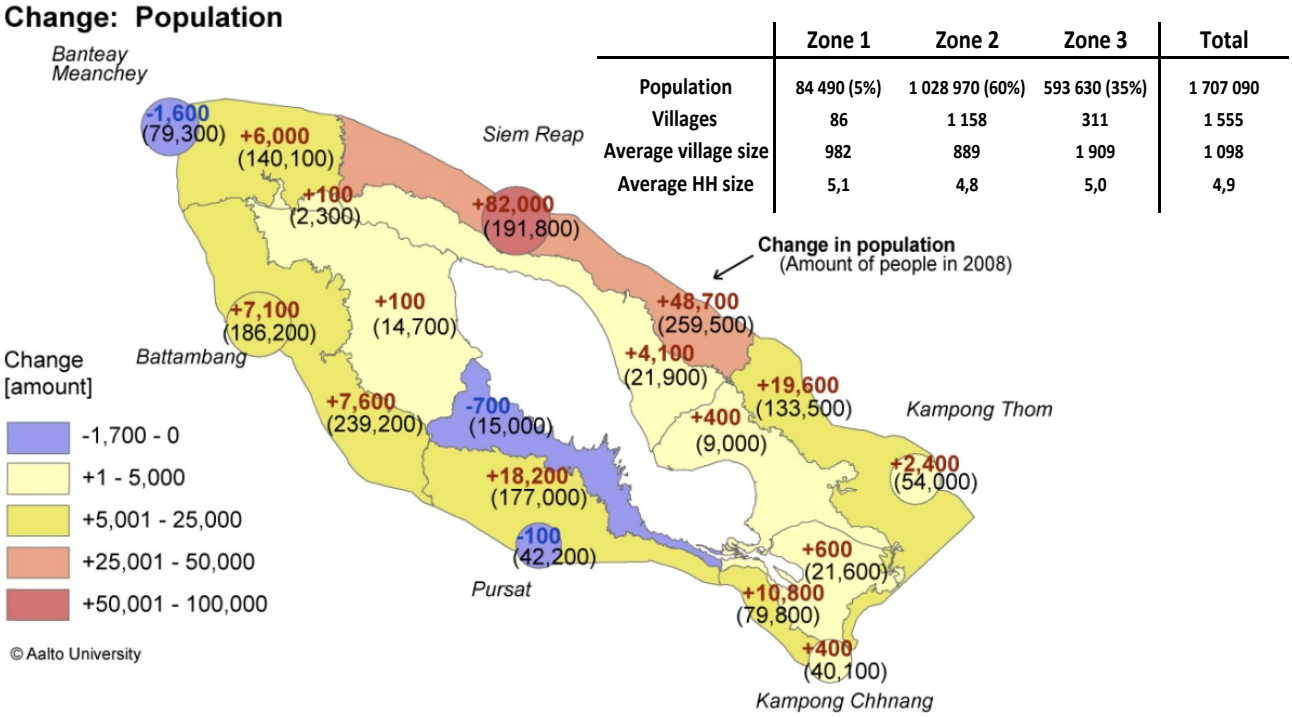
According to MRC/IKMP (2010), the current hydropower plans alone would result in 50% or more decrease in the Tonle Sap primary productivity in large areas of the lake proper and in the floodplains. While the connection between primary production and fisheries remains unstudied (see e.g. Lamberts 2006; Lamberts & Koponen 2008), such a change would without doubt have a significant negative impact on the Tonle Sap fisheries as well. In addition, the dams would also result in sediment trapping that is estimated to decrease the amount of bioavailable phosphorus input to the Cambodian floodplains and Delta by 10'000-18'000 tonnes per year, thus having a negative effect also on agricultural production (MRC/IKMP 2010). Arias (2013) –drawing partly on the work of MRC/IKMP (2010)– provides similar range estimates, noting that Mekong hydropower development is likely to reduce Tonle Sap's aquatic primary production by 33% and the combined impact of climate change and hydropower by up to 41%.

This kind of major reduction in primary productivity and, consequently, fisheries, is similar to the estimates provided by MRC (2010: 46), where it is noted that: "the ecology and primary productivity of the Tonle Sap system could change significantly through the simultaneous interaction of all above threats: reduced flooding, reduced reverse flows, and reduced inflow of nutrients associated with fine sediments (caused by the Definite Future Scenario) and the large decline in fisheries and biodiversity caused by the additional developments in the 20-Year Plan Scenario (with all LMB mainstream dams)". The report concludes that already under the Lower Mekong Basin 20-Year Plan Scenario (11 mainstream dams and 30 tributary dams + irrigation and water supply projects), white fish production in the area could be reduced by 50% and the possibilities for local people to collect

timber and non-timber products from the wetlands reduce. MRC (2010) also emphasises that the dams' blockage of the migration paths (particularly by the two proposed mainstream dams in Cambodia) will significantly reduce the large number of ecologically and commercially important fish species in the Tonle Sap. See also Ziv et al. (2012).

Changes in socio-economic setting[12]

The single most important socio-economic change factor in the Tonle Sap is the fact that the area's population is growing relatively fast, although somewhat unevenly (Figure 9). The population of the Tonle Sap area increased from 1.5 million in 1998 to 1.7 million in 2008, indicating an increase of 14%. Population growth was more intensive in the Urban Zone (growth: 18%), while in the Zone 2 (Upper Floodplain) the growth was 12%. In the Zone 1 (Lower Floodplain) the population growth was 6%. The majority of the population growth occurred in the province of Siem Reap (40% growth in population), with the second largest growth taking place in Kampong Thom (growth of 13%).



	Zone 1	Zone 2	Zone 3	Total
Population	84 490 (5%)	1 028 970 (60%)	593 630 (35%)	1 707 090
Villages	86	1 158	311	1 555
Average village size	982	889	1 909	1 098
Average HH size	5,1	4,8	5,0	4,9

Figure 9. Change in population for different zones in Tonle Sap. Figures indicate change in the amount of population (blue decrease, red increase): in parentheses total population in 2008. Table shows the total population and amount of villages in each zone. Data from Population Census 1998 and 2008

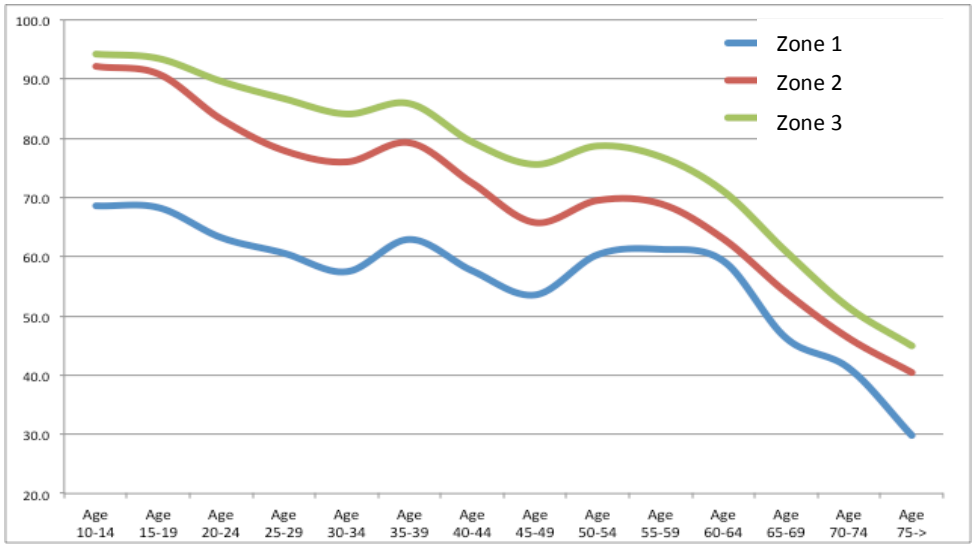
[12] Following two chapters provide information about the change from year 1998 and 2008 for selected socio-economic and livelihood indicators, based on data derived from Population Census: for more, see Baseline Report (Keskinen et al. 2011). According to our knowledge, this is the first socio-economic analysis done specifically in the Tonle Sap area using the data from Population Census 2008. Even more importantly, we are not familiar with any other study in entire Cambodia that would have utilised both Census 1998 and Census 2008 to recognise socio-economic trends at this level of detail. Unlike the chapter on possible changes in flood pulse (that drew on the modelling of the hydrological impacts of possible future changes by 2042), we are in this chapter thus describing actual trends and changes that have happened between 1998 and 2008. Information on these trends is complemented with the findings from CSIRO Tonle Sap Household Survey 2011 (CSIRO 2011; Ward & Poutsma 2013), including respondents' perceptions about different key drivers. Based on this information, we then come up with some hypothetical suggestions for possible socio-economic changes in the near future.

The fact that the biggest age groups in the Tonle Sap are currently young people between 15-24 years old has, we believe, very strong implications to the future development of the area. Most importantly, the **'youth surge'** means that the Tonle Sap area is just now seeing a large amount of young people entering the work force. The Tonle Sap area is, similarly to entire Cambodia, thus seeing a possibility for the so-called demographic dividend, where a rising proportion of working age people –and, consequently, decreasing dependency ratio– can lead to increased development and economic growth (Bloom et al. 2003; Ross 2004; Keskinen 2008). This requires, however, a development context that provides meaningful possibilities for employment: otherwise the increase in work force can also lead to accelerating environmental and social problems when more people compete for the same limited natural resources.

The increasing proportion of working age people is already visible from the databases as well. The amount of Economically Active Population[13] has increased from 1998 to 2008 remarkably in all three zones, from 42.8% to 52.7% in Zone 1 (Lower Floodplain), from 41,4% to 52,1% in Zone 2 (Upper Floodplain), and from 35,2% to 45,4% in Urban Zones. In total, approximately half (49,8%) of the total population in the Tonle Sap area were economically active in 2008, compared to 39,4% ten years earlier.

The possibility to make use of this on-going increase in working age people depends from variety of factors, not least from the existing governance context (Bloom et al. 2003; Keskinen 2008). Education matters, as well. The general level of education in the Tonle Sap remains low, with over half of the population having either no education (22%) or having not completed primary education (33%). The situation is, however, changing, and particularly the proportion of people having completed primary and lower secondary education has improved between 1998 and 2008, indicating that younger generation is better educated than the elder. Similar trend is visible in terms of literacy rates, with the youngest age groups being more literate than the elder (Figure 10). There are also notable differences in literacy between the zones, with Zone 1 (Lower Floodplain) having clearly the weakest literacy rates (see also Annex C). There seems to be no remarkable differences between the literacy rates of men and women (Annex F).

[13] Economically Active Population is defined as the people who have responded to be involved in one or more livelihood activity, including also people who are temporarily unemployed. It thus excludes children, students, retired and other persons who have never been working.



Urban areas act in many ways as the 'engines of change' in the area, with Siem Reap and its rapidly growing service and tourism sectors having a special role. The level of infrastructure in urban areas is generally better and the livelihood sources clearly more diverse –and much less dependent on natural resources– than in rural areas. For example, the access to sanitation in Urban Zone is at 73% much higher than in other zones (22-28%). The situation is similar in terms of access to power: while only 29% of all households had in 2008 access to continuous electricity supply (termed 'city power' in the Census), in the Urban Zone this proportion increased from 32% in 1998 to 67% in 2008. Also the education level is better in urban than rural areas, and this difference seems to be increasing: the education level between 1998 and 2008 increased more rapidly in urban than rural areas, with the proportion of people who have not completed primary education increasing in some rural areas, particularly close to the lake.

As a corollary, the urban areas attract both seasonal and permanent migrants. This seems to be reflected in the statistics about the home ownership as well: while a clear majority of the homes in the area are owner occupied, the proportion of households renting their apartment in the Urban Zone increased by 8 percentage points between 1998 (3%) and 2008 (11%), and by 21 percentage points in Siem Reap, where 24% of all households lived in a rented apartment in 2008.

Yet, the findings from the CSIRO Tonle Sap Household Survey (Ward & Poutsma 2013) indicate that the majority of the people are not willing to migrate even when facing challenges with their current livelihoods activities, but prefer to stay at their home villages. Hence, it seems that the migration to urban areas has not so much to do with urban pull, but rather with rural push[14]: people migrate not so much because of the attractive employment opportunities provided by the cities and provincial town, but due to inability to make their ends met in their home villages (see also Haapala 2003; Heinonen 2006, 2009).

[14] The rural push indicates here the pressure that makes people move from rural areas, and is caused by multiple factors such as population growth, problems in the agricultural sector and fishing, declining natural resources and, in general, reduced living standards and poverty (Heinonen 2009). Urban pull constitutes then factors that draw people to the urban areas, including e.g. better employment opportunities and increased education possibilities (Heinonen 2009).

Changes in livelihoods

As of today, the Tonle Sap remains a predominantly agricultural area. Although agriculture's role has decreased from 66% of total work force in 1998 to 61% in 2008, the majority of the people still rely on agriculture as their main source of livelihood. In addition, due to population growth, the amount of people in the agricultural sector has increased considerably: from 3.7 million in 1998 to 4.9 million in 2008. Fishing remains an important source of livelihood particularly in the villages close to the lake, with 4.5% of total work force, or 38' 250 people, having fish as their main livelihood in 2008 (1998: 4.7%).

Yet, some signs for increasing livelihood diversification are visible as well. The most rapidly growing livelihood sector in the Tonle Sap was construction, which increased from 1% in 1998 to 4% in 2008: this is similar to the national trend. Other increasing (although still minor) livelihood sectors include manufacturing, hotels and restaurants, other service activities, hotels and restaurants, and real estate, renting and business activities (Figure 11). Yet, while for example manufacturing is growing fast in Cambodia and is currently the 3rd biggest industry nationally (2008: 6.2% of all work force), in Tonle Sap its role is at 3% clearly less.

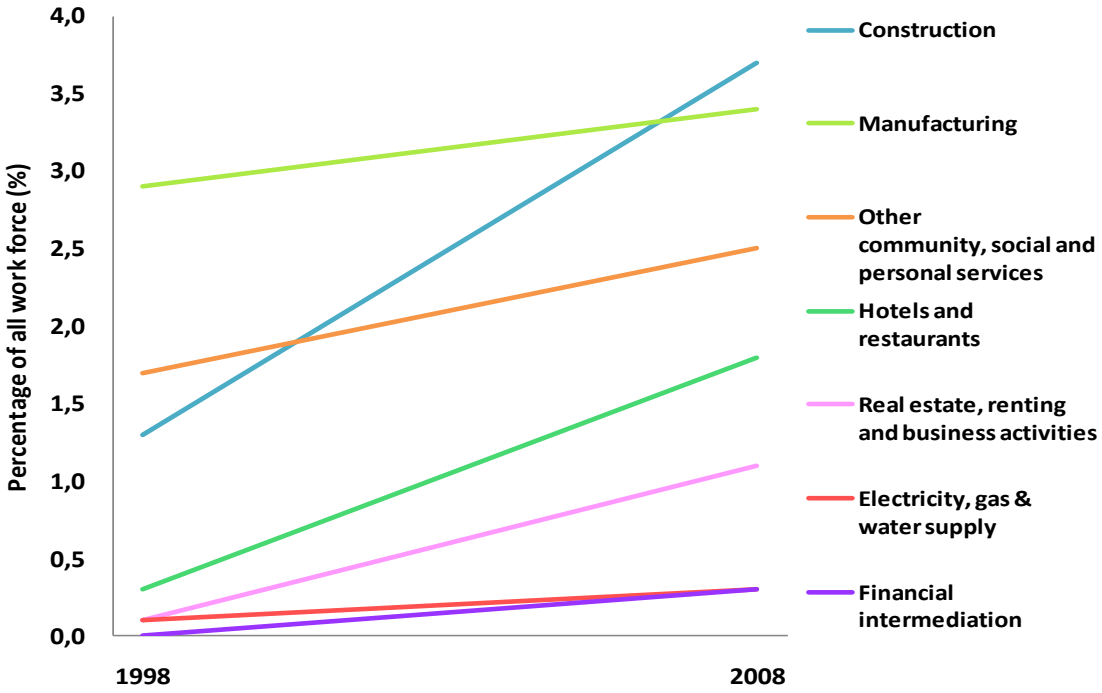


Figure 11. The most rapidly growing industry sectors in the Tonle Sap area between 1998 and 2008, based on the data available from Population Census 1998 and 2008. Note that the trends are based only on two data points, and should therefore be considered as very rudimentary.

The Census data indicates that there are quite remarkable differences *within* each zone as well, as **each of the 18 sub-zones used in this study have quite differing socio-economic and livelihoods trends** as well (e.g. Annex D and Annex E). For example, the sub-zone 1 in Pursat is the only sub-zone 1 (Lower Floodplain) where the population decreased between 1998 and 2008: in all other sub-zones 1 (as well as most other sub-zones) the population increased during the same period.

Economic Active Population (EAP) increased by far the most in Siem Riep's Urban Zone, where the increase 1998-2008 was more than 54% (46'900 people). In comparison, the increase of EAP in other Urban sub-zones was much less (e.g. Pursat 20% and Battambang 25%), as was the increase in other zones of Siem Reap (Zone 2: 34%, Zone 1: 37%). For more information on the differences between sub-zones, see the Annex D of our Baseline Report (Keskinen et al. 2011).

The Tonle Sap Household Survey 2011 (CSIRO 2011, Ward & Poutsma 2013) provides interesting information about the respondents' perceptions of their future within next 5–10 years, including possible changes in their livelihood activities and in the environment and water resources. Interestingly, there are clear differences between the different zones. For example, the respondents living in Zone 1 (Lower Floodplain) see increasing variability of weather as well as decreasing amount of fish more likely than the respondents from other two zones (Table 6). These two drivers were also the ones that most respondents considered to have negative impact to the respondents' households, with the respondents from the Zone 1 (Lower Floodplain) seeing that they will have very strong negative impact to their lives.

The perceptions on different drivers also indicate that the survey respondents consider reduced availability of water due to increased water use (other than agriculture) not very likely to occur, compared e.g. to the likelihood of water becoming more polluted or weather more variable. Similar trend is visible in terms of migration, which the respondents don't consider a very likely driver in their villages and also see its impact not to be very strong to their households. Remarkably, a majority of the people in all three zones (58–68%) considered that the possible migration to their villages would have a positive impact to their lives: this finding thus somewhat challenges or at least enriches the view that migrants would commonly be seen as a some kind of threat by the people already living in the area. For more information on the survey and its results, please refer to Ward & Poutsma (2013).

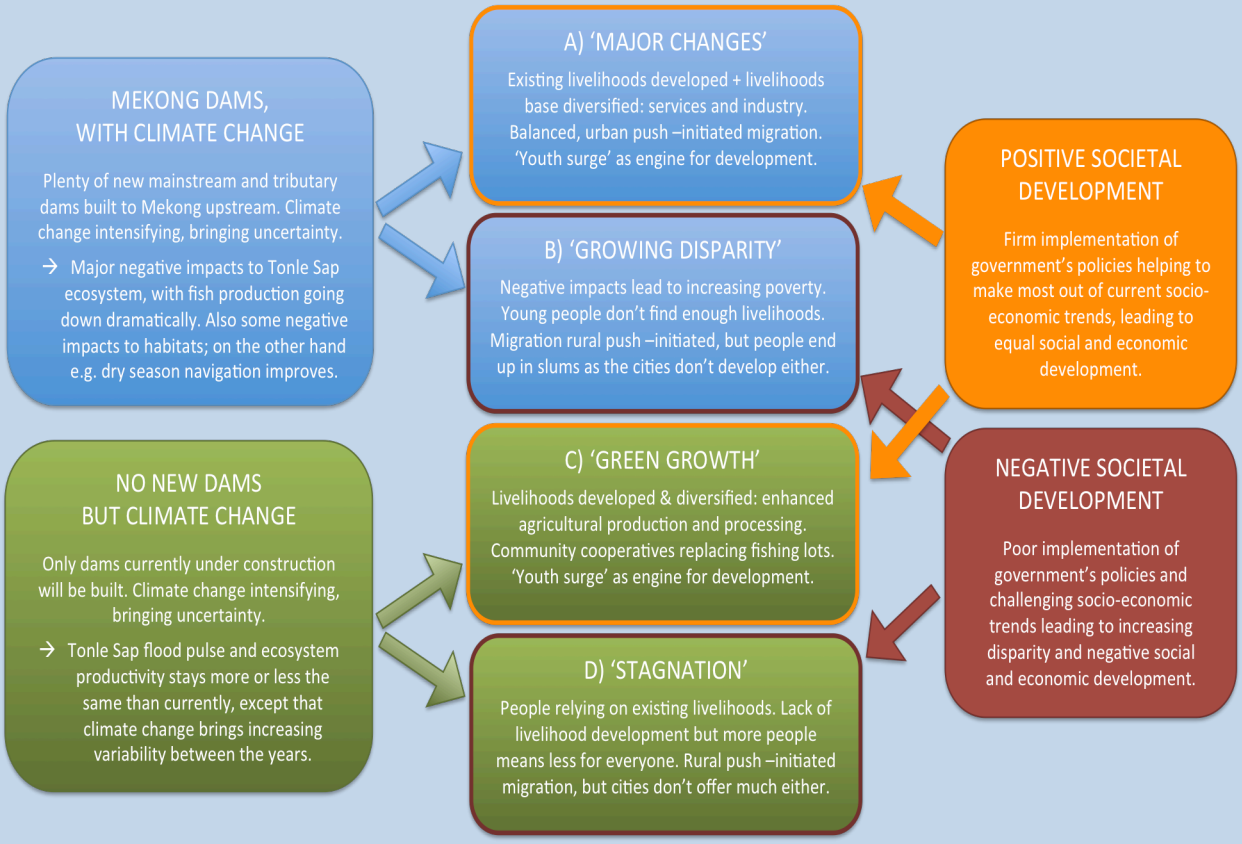
Table 6. Respondents' perceptions of changes, including their likelihood and impact to the household. Respondents were asked[15]: 'In your personal view, how likely is any of this to happen in your region in the next 5-10 years?' and 'In your personal view, if any of this happens in your region in the next 5-10 years, will it affect your household?'. Table based on the data from the CSIRO Tonle Sap Household Survey 2011.

RESPONDENTS' PERCEPTIONS: HOW LIKELY IT WILL BE IN THE NEXT 5-10 YEARS? *(0 = no way will happen … 6 = will happen for sure)*		**Zone 1 (Lower Floodplain)**	**Zone 2 (Upper Floodplain)**	**Zone 3 (Urban)**	**TOTAL for three zones**
Number of households responding		*80*	*716*	*144*	*940*
Weather becomes more variable		**4.4**	**4.1**	**3.7**	**4.1**
How likely it is that this will impact your household?		4.9	4.4	3.7	4.3
Will it impact you positively or negatively?	Negative	93.7%	93.7%	91.7%	93.4%
	Neutral	0.0%	0.4%	0.7%	0.4%
	Positive	6.3%	5.9%	7.6%	6.2%
Water will become more polluted		**3.8**	**3.7**	**4.0**	**3.7**
How likely it is that this will impact your household?		4.1	3.8	4.0	3.9
Will it impact you positively or negatively?	Negative	87.5%	80.9%	84.0%	81.9%
	Neutral	0.0%	0.6%	0.7%	0.5%
	Positive	12.5%	18.5%	15.3%	17.5%
Fish & other aquatic resources decline from rivers and floodplains around the village		**4.5**	**4.2**	**4.0**	**4.2**
How likely it is that this will impact your household?		4.7	4.2	4.0	4.2
Will it impact you positively or negatively?	Negative	94.9%	95.1%	90.3%	94.4%
	Neutral	0.0%	0.3%	2.8%	0.6%
	Positive	5.1%	4.6%	6.9%	5.0%
You will continue to grow rice because of food security		**4.1**	**4.1**	**4.3**	**4.2**
How likely it is that this will impact your household?		3.6	3.9	3.0	3.7
Will it impact you positively or negatively?	Negative	8.8%	9.3%	7.6%	9.0%
	Neutral	0.0%	1.4%	2.1%	1.4%
	Positive	91.3%	89.3%	90.3%	89.6%
Irrigation system will be built and everyone has plenty of water to grow crops all year round		**2.7**	**4.1**	**4.0**	**4.0**
How likely it is that this will impact your household?		3.2	3.8	3.3	3.7
Will it impact you positively or negatively?	Negative	6.3%	5.0%	2.1%	4.7%
	Neutral	1.3%	1.0%	2.8%	1.3%
	Positive	92.4%	94.0%	95.1%	94.0%
There will be less water, as there will be many water users (other than agriculture) in the future		**2.7**	**2.9**	**2.5**	**2.9**
How likely it is that this will impact your household?		3.8	3.2	2.6	3.1
Will it impact you positively or negatively?	Negative	56.3%	59.0%	52.1%	57.7%
	Neutral	0.0%	2.8%	3.5%	2.7%
	Positive	43.8%	38.2%	44.4%	39.6%
People from elsewhere will move into your village		**2.9**	**3.1**	**3.3**	**3.1**
How likely it is that this will impact your household?		3.4	3.1	2.8	3.1
Will it impact you positively or negatively?	Negative	41.3%	25.4%	20.1%	25.9%
	Neutral	1.3%	7.0%	11.8%	7.2%
	Positive	57.5%	67.6%	68.1%	66.8%

[15] The responses rated according to Likert scale with following seven levels: 0 = no way that can happen, 1 = very unlikely this will happen, 2 = unlikely this will happen, 3 = maybe, 4 = likely this will happen, 5 = very likely this will happen, 6 = it will happen for sure.

PART 3: TONLE SAP IN 2040 – FOUR ALTERNATIVE FUTURES

- In this part, we will discuss **how the Tonle Sap could look like by year 2040** when considering the interconnections between water, natural resources and livelihoods.
- We **synthesise our research findings by creating four alternative futures for the Tonle Sap in 2040**, building on water- and livelihoods-related changes and trends that we feel are possible to occur in the area (Figure below[16]; bigger version available in Annex G).
- The four alternative futures for the Tonle Sap build on two possible **'water paths'** (one with plenty of Mekong dams, other with no new Mekong dams) as well as two **'societal development paths'** (good and not-so-good socio-economic development).
- The 'societal development paths' are strongly dependent on the implementation –and non-implementation– of the **government's development policies** in the area. Hence, we also recognised most relevant policy objectives for the Tonle Sap (Annex I).



[16] Figure shows the process of creating four alternative scenarios for Tonle Sap (A – D). The summaries for two 'water paths' given in the boxes on left, while the summaries of the two differing 'societal development paths' are visible in the boxes on right.

This Final Report has presented an overview of the current situation (Part 1) and discussed trends and changes (Part 2) related to water resources and livelihoods in the Tonle Sap area. The analysis has been based on hydrological, environmental and socio-economic information derived from the hydrological databases, Population Census 1998 and 2008, Cambodian Socio-Economic Surveys as well as the CSIRO Tonle Sap Household Survey. This quantitative information has then been complemented by and compared with information –quantitative and qualitative– available from other sources, including different livelihood-related village surveys (e.g. Keskinen 2003, 2006; ADB 2007; Nuorteva 2009) as well as other relevant reports, such as CNMC's Tonle Sap Sub-area Analysis Reports (CNMC 2004; Mak et al. 2012). Together, these information sources have provided what we believe to be a rather precise and objective account of the main hydrological and livelihood-related characteristics of the Tonle Sap area.

In Part 3 of the Final Report, we will take a look towards future, discussing how the Tonle Sap may look like by year 2040. Future is, of course, uncertain and dependent on the decisions we make. Consequently, the analyses presented in this report as well as in Baseline Report (Keskinen et al. 2011) provide differing views for water- and livelihood-related future changes in the Tonle Sap. These views also include major uncertainties and unknowns on, for example, the impacts of climate change as well as on key aspects related to social and economic development and their linkages to environment and natural resources. Socio-economic development is, after all, never linear and any trend analysis of past socio-economic data is therefore unlikely to hold true for long. For these reasons, we felt that it doesn't make sense to generate just one view about the ways the possible changes and trends in water and livelihoods are likely to shape the Tonle Sap in the future.

Instead, we decided to provide a synthesis of our research by creating four alternative futures –or scenarios– for the Tonle Sap in 2040, building on possible changes and trends that water and livelihoods will bring to the area. The findings presented above influenced therefore greatly to the way the four alternative futures were formed: they essentially formed the frames within which we allowed us to create the alternative futures. In this way our alternative futures –while making use of scenario techniques– can be seen to be close to data- and analysis-based forecasts. In other words, they build on our modelling estimates and trend analyses and don't include major surprises or irregularities[17]. There are also other, more innovative and less rigid ways to create scenarios: see e.g. Schwartz (1996), van Notten et al. (2003, 2005), Mahmoud et al. (2004), van Notten (2006), Foran et al. (2011), Heikinheimo (2011), Smajgl et al. (2011) and Zhu et al (2011).

Overall, we feel that the following scenario description captures well the main characteristics of our four alternative futures as well:

> "*A scenario is a coherent, internally consistent and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold.*" (IPCC 2012)

[17] Using the scenario typology of Van Notten (2006), our alternative futures aim for decision support by deciphering the large amount of information and integrating possible future developments into consistent pictures of the future. They are also evolutionary, as they consider the development of the Tonle Sap to be largely gradual and incremental, without major discontinuities and surprises.

The four alternative futures presented in this report are not the same than the future-oriented scenario narratives created during the first and second Tonle Sap Futures workshops (Foran et al. 2011). Yet, the alternative futures presented here do share similarities with those narratives, and for example some of the drivers and trends described in the narratives are also included in the alternative futures (e.g. hydropower, irrigation, new agricultural techniques, migration patterns).

Given that our study looks at water-energy-food nexus (Hoff 2011; ERD 2012; Bach et al. 2012) and focuses on the linkages between water and people, the starting point for the formulation of our alternative futures was the decision to build (or not) more mainstream and tributary dams in the Mekong upstream. This decision created then two alternative 'water paths' –and the related 'energy paths'– for the scenario process (Annex G): one with plenty of Mekong dams (blue path) and one with only Mekong dams currently existing or under construction (green path).

Following, the differences in the socio-economic and livelihood development by 2040 led to two different kinds of 'societal development paths': one good and one not-so-good. The 'societal development paths' build on our analysis of socio-economic and livelihoods trends, but they are also very closely linked with key government strategies for the development of the Tonle Sap: in this way they could thus also be called 'policy paths'. Of the different governmental strategies, we have particularly used the key focus areas of Cambodia's Rectangular Strategy, described in National Strategic Development Plan and its Update 2009-2013 (RGC 2006, 2010; Figure 12; Annex I).

Together, two 'water paths' and two 'societal development paths' create then four alternative futures for the Tonle Sap by 2040. The qualitative descriptions for the four alternative futures were drafted in a brainstorming session at Aalto University and written by the main author of the report, making use of the earlier Tonle Sap scenarios developed by Heikinheimo (2011). The four alternative futures for the Tonle Sap area in 2040 created are:

A) Major changes

B) Growing disparity

C) Green growth

D) Stagnation

Each alternative future is thus similar to two other alternative futures: they either share same 'water path' or have similar 'societal development path' (Annex G). In this way our alternative futures differ from conventional scenarios that seek to be more clearly different from each other. It is also important to note that four alternative futures do not represent the only possible futures for the Tonle Sap.

Yet, we do believe that our four alternative futures do capture the trajectories that *potentially* follow from the transformations we expect to happen in the area due to: a) changes in water flows due to water resources development in the Mekong River Basin and/or climate change, and b) current socio-economic and livelihood trends –and the related policies– in the Tonle Sap area. In this way, we feel that all four alternative futures represent *possible* and, in terms of policy implementation, *realisable* scenarios for the Tonle Sap area by 2040 (Mahmoud et al. 2012).

Linkages with the Government's development strategy

The alternative futures described in this Part build on our analysis, yet include also many uncertainties and assumptions due to their forward-looking nature. Importantly, the four alternative futures depend greatly on the decisions made by the Royal Government of Cambodia and the related organisations –ministries, provincial authorities, Tonle Sap Authority and so forth– in relation to the development of the Tonle Sap and, indeed, the entire country.

Consequently, before formulating the alternative futures for the Tonle Sap, it is important to consider what kind of policies the Royal Government of Cambodia has in relation to the area. The most relevant such strategy is **Cambodia's Rectangular Strategy**, described in National Strategic Development Plan Update 2009-2013 (RCG 2010; Figure 12).

In general, the Rectangular Strategy focuses on several aspects that we consider critical for the development of the Tonle Sap area. Remarkably, all key emphases of the strategy are very relevant in the Tonle Sap area as well, including 1) Enhancement of agricultural sector (incl. fisheries reform), 2) Private sector development and employment generation, 3) Capacity building and human resource development (incl. education, health and social safety nets), 4) Rehabilitation and Construction of physical infrastructure (incl. water resources and irrigation) as well as 5) Good governance (RCG 2010; Figure 12). At more detailed level, we selected some precise objectives that we feel are particularly relevant for the future development of the Tonle Sap area – and hence also for the creation of the four alternative futures for the Tonle Sap: see the list in Annex I.

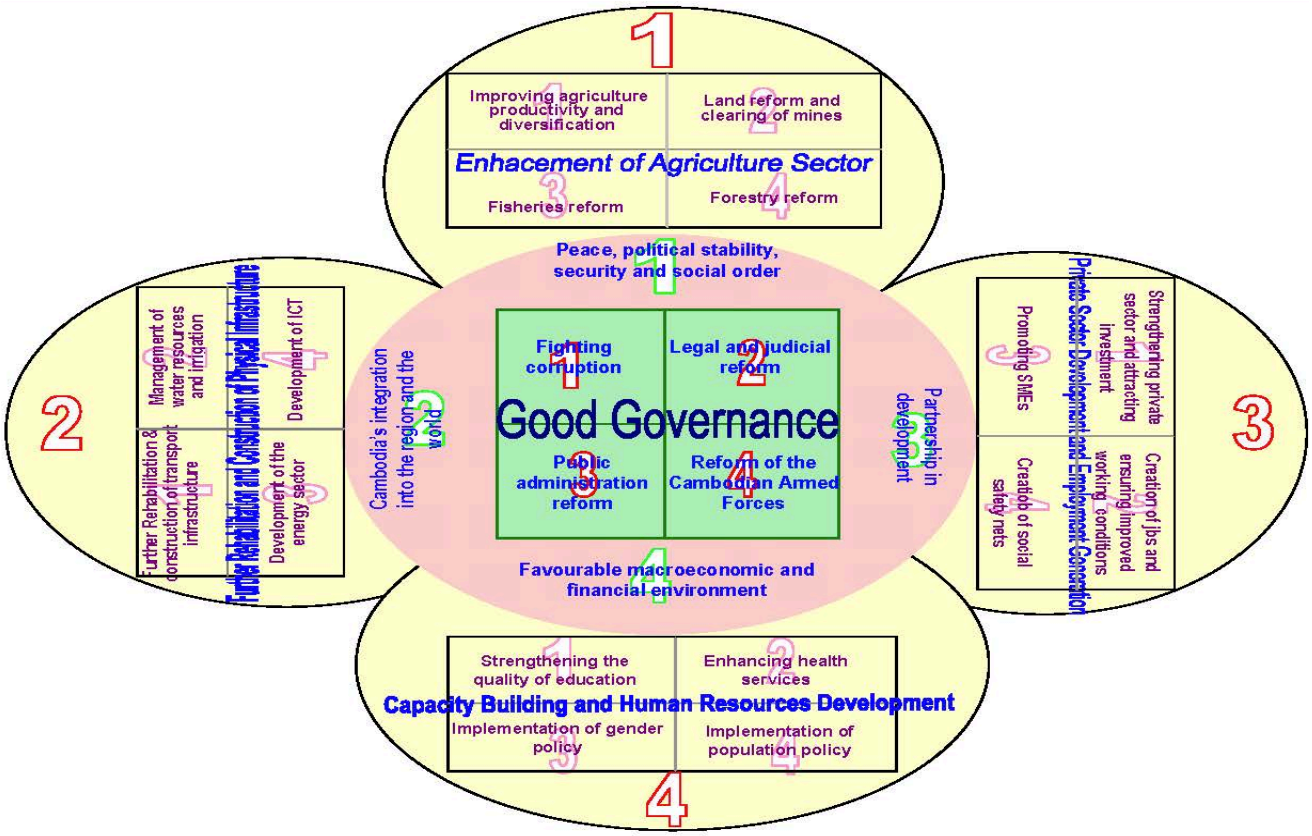


Figure 12. General structure of Cambodia's Rectangular Strategy Phase II (RGC 2010).

A) Tonle Sap in 2040: Major changes

Dam building impacting Tonle Sap flood pulse and floodplains

This 'alternative future' includes **intensive hydropower dam building in the Mekong upstream**: most of the dams located in the Mekong mainstream and tributaries in Lao PDR that has benefited most from the development. Cambodia is in this 'alternative future' assumed to have built several tributary dams in the 3S Rivers area and two dams to the Mekong mainstream upstream from Kratie by 2040: these **dams provide much needed energy** to the country, reducing the use of fossil fuels and increasing energy sovereignty (reduced dependency on energy export).

The dams have, however, caused **major impact to the Tonle Sap flood pulse**, which has led to remarkable negative impact Tonle Sap aquatic productivity. There has been increase in dry season water level, resulting to the loss of up to 80% of the tall gallery forests ('flooded forests') surrounding the lake. Together with decreased wet season water levels, the total area of floodplain area has reduced. The nutrient-rich sediment flux from the Mekong has been cut to half, and the mainstream dams have blocked the fish migration routes. All in all, these changes have lead to reduced nutrient input into the floodplain and, most importantly, to radical reduction in the amount of fish and other aquatic animals: **fish catches have declined by approximately half i.e. 50%.**

On the other hand the changes in water levels have also positive impacts: navigation has improved considerably during the dry season, and the reduced flood peak means that **the area available for the agriculture in the upper parts of the floodplain has increased by 5-10%.**

Climate change is by 2040 visible through **increased frequency of extreme weather events** and changed precipitation and temperature patterns, which also impact Mekong water flows. While increased amount of storms and draught periods cause periodic challenges particularly to agriculture, all in all the impacts from climate change are clearly less than those from Mekong dams.

Socio-economic development + migration

People who belonged to the so-called youth surge in 2012 have reached middle age, being 45-55 years old. Thanks to the government's successful health and birth spacing policies, the fertility rates have declined, meaning that the **family sizes are smaller** and the age groups born between 2012-2040 considerable smaller: this has reduced the dependency ratio. The government's active education policy means that younger age groups are also much **better educated** than in 2000s, with many young people completing high school. All in all, the **demographic dividend has worked well and it has –together with successful government policies and governance reforms– provided a window of opportunity to develop existing livelihoods as well as to create new ones.**

Migration from rural areas to urban areas has been considerable but still rather balanced. **Migration initiated by 'urban pull'** i.e. availability of decent work and housing in district towns and provincial capitals, and to lesser extent by 'rural push' i.e. lack of livelihood opportunities in rural areas. Reduction in fish catches has forced people from the Zone 1 (Lower Floodplain) to migrate to urban areas, where they have without proper skills and connections ended up with temporary, low-paid jobs.

Those migrating from rural areas to urban areas move usually permanently, and as a result the **urbanisation rate in the entire Tonle Sap is already over 60%:** a majority of the people are thus already living in urban areas. The amount of urban areas has also grown: most district towns are now already cities, and several major villages have been turned into bustling towns. Many have migrated also to Phnom Penh or even abroad.

Livelihoods

The proportion of **people involved in agriculture has reduced** since 2010s, but agriculture is still very important livelihood source in the rural areas. Improved irrigation, increased fertilizer use and agricultural mechanization have led to considerably **increase in agricultural productivity**, both per hectare and per working hour. Reduced flooding in the upper parts of the floodplain has led to 5-10% **increase in the area of agricultural fields**. Yet, due to decreased water availability, some paddy fields have been turned into less water-consuming fruit orchards and soya & vegetable fields.

Major **decline in fisheries** means that only some people are able to make living out from fishing. Yet, the government's efforts to promote sustainable natural resource use and ensure equal access to aquatic resources (fisheries reform) have in general supported fishing as a livelihood. Majority of the current 100'000 ton fish catch comes from community cooperatives using large-scale fishing gears such as bagnets: cooperatives replaced the private fishing lots in 2010s.

Both agricultural and fish processing have developed, and all provincial capitals and most district towns have their own **food processing factories** that produce agricultural end products. Due to major reduction in fish and hence protein, however, a great majority of the products go for both domestic market and **only 10% of the food products is exported.** In addition, the amount of processed fish products is limited due to reduced fish catches.

In urban areas the most important sources of employment are industry, service (incl. tourism) and construction sectors. The **industry is increasingly non-agricultural**, including garment factories, manufacturing parts for mobile phones and computers and lately also gaming industry. In district cities and towns, however, agricultural industry is the main employee, with workers commuting also from the surrounding rural areas to work. The growing industry, service and construction sectors require increasing amount of work force, and as a result plenty of young people –usually those with highest education– have migrated permanently to cities and towns for work.

Remarks

Food security remains the major challenge. Radical reduction in fish catches has meant that the Cambodians have lost their main protein source. Replacing the lost protein is not easy, and it needs to be done with mixed methods: growing and processing more soya beans as well as increasing the amount of cattle. This requires, however, plenty of water and land (Orr et al. 2012). Yet, Cambodia still needs to import considerable amount of its animal protein and this is costly.

Environmental impacts from increased fertilizer use, growing cities and industry cause pollution and eutrophication. Despite the reduction in fisheries and other water-dependent resources, the demographic dividend that started in 2010s has created positive outcomes: due to livelihood diversification also the dependency on agriculture and fisheries has reduced.

B) Tonle Sap in 2040: Growing disparity

Dam building impacting Tonle Sap flood pulse and floodplains

This 'alternative future' includes **intensive hydropower dam building in the Mekong upstream**: most of the dams located in the Mekong mainstream and tributaries in Lao PDR that has benefited most from the development. Cambodia is in this 'alternative future' assumed to have built several tributary dams in the 3S Rivers area and two dams to the Mekong mainstream upstream from Kratie by 2040: these **dams provide much needed energy** to the country, reducing the use of fossil fuels and increasing energy sovereignty (reduced dependency on energy export).

The dams have, however, caused **major impact to the Tonle Sap flood pulse**, which has led to remarkable negative impact Tonle Sap aquatic productivity. There has been increase in dry season water level, resulting to the loss of up to 80% of the tall gallery forests ('flooded forests') surrounding the lake. Together with decreased wet season water levels, the total area of floodplain area has reduced. The nutrient-rich sediment flux from the Mekong has been cut to half, and the mainstream dams have blocked the fish migration routes. All in all, these changes have lead to reduced nutrient input into the floodplain and, most importantly, to radical reduction in the amount of fish and other aquatic animals: **fish catches have declined by approximately half i.e. 50%.**

On the other hand the changes in water levels have also positive impacts: navigation has improved considerably during the dry season, and the reduced flood peak means that **the area available for the agriculture in the upper parts of the floodplain has increased by 5-10%.**

Climate change is by 2040 visible through **increased frequency of extreme weather events** and changed precipitation and temperature patterns, which also impact Mekong water flows. While increased amount of storms and draught periods cause periodic challenges particularly to agriculture, all in all the impacts from climate change are clearly less than those from Mekong dams.

Socio-economic development + migration

People who belonged to the so-called youth surge in 2012 have reached middle age, being 45-55 years old. The fertility rates have declined a bit, but are still rather high: family sizes particularly in rural areas remain large and as a result **population keeps growing**. The education level has slowly improved, but there are considerable differences between urban and rural areas: most of the youth in rural areas complete still only primary school. Due to poverty they are also less healthy. All in all, the **government's policies on health, education and poverty reduction have been implemented with varying success,** and the situation in many rural areas is particularly challenging.

Migration from rural areas to urban areas has been massive, being primarily initiated by 'rural push' i.e. loss of livelihoods and lack of food security in rural areas. Reduction in fish catches has forced majority of people from the Zone 1 (Lower Floodplain) to migrate to urban areas, while decreasing agricultural production per capita means that also plenty of people from the Zone 2 (Upper Floodplain) have migrated to cities and towns. However, as there are not much work opportunities in urban areas either, **several people migrating to cities have only temporary, low-paid jobs or are unemployed**.

Those migrating move usually permanently, and as a result the urbanisation rate in the entire Tonle Sap is already **close to 75%:** a great majority of the people are thus already living in urban areas. The amount of urban areas has also grown: most district towns are now already cities, but many of them have also considerable slums accommodating rural migrants.

Livelihoods

Agriculture is still the most important livelihood source in the rural areas. However, the poor implementation of the government's agricultural policies has led to the lack of capital, innovation and physical infrastructure for agriculture. As a result, the **agricultural production has in general not improved** much, and only those who are better off can afford to invest to the infrastructure needed for agricultural development. At the same time several small-scale farmers have got into debt, and have been forced to sell their land: the **farm sizes have thus increased** and agricultural production been concentrated into fewer people. As the population growth continues to be rapid, the agricultural production per capita has been reduced.

The major **decline in fisheries** means that only small amount of people are able to be fisher anymore. In addition, as the fisheries reform hasn't really progressed as planned in 2010s, half of the current 100'000 ton fish catch comes from large-scale fishing activities. As a result, the remaining small-scale fishers have challenges to make their ends meet, and they had thus to find alternative livelihood sources. During the 2020s ex-fishers cut down the last areas of the remaining forest and large shrubs in the Tonle Sap floodplain: this lead to further reduction in the fisheries.

In urban areas the most important sources of employment are industry, service and construction sectors: particularly industry has been growing thanks to cheap and reliable energy available from Cambodia's hydropower dams. Given the diminishing small-scale agricultural production and reducing fish catches, the **industry is increasingly non-agricultural**: electronic manufacturing (laptops, mobile phones etc.) is growing particularly rapidly. In addition, some companies focus on food processing of the agricultural products derived from large-scale farms. Lack of livelihood options in rural areas have led to massive migration to urban areas, but most of these people don't have job in urban areas either.

Remarks

Food security remains the major challenge. Radical reduction in fish has meant that the Cambodians have lost their main protein source, and replacing it would require increasing amount of cattle as well as cultivation of soya bean, wheat etc.: all this requires plenty of water and land as well as new farming techniques, which are not widely available. Stagnant agricultural production thus means that there is simply not enough food for everyone: this has resulted in increasing import of food, raising food prices and, hence, increased poverty.

Increasing disparity both within and between urban and rural areas can potentially lead to major social and political unrest: those more well-off have to live in fenced compounds to protect themselves and their property.

C) Tonle Sap in 2040: Green growth

Tonle Sap flood pulse preserved, supporting high aquatic production

Under this 'alternative future', the Mekong dam building ceased in 2010s, and **large-scale hydropower was replaced by more decentralised energy production,** building on renewable energy such as solar, wind, biomass and micro-hydropower (see e.g. CRCD 2004, 2006; World Bank 2006; Ryder 2009; Toch 2010). Energy plans were also revised to focus on energy saving measures, leading to major slow down in the increase of energy consumption.

Without new large-scale dams since 2010, **water flows of the Mekong and Tonle Sap flood pulse are close to natural still in 2040.** Also influx of the nutrient-rich sediments from the Mekong to the Tonle Sap floodplain has been maintained. The water-dependent resources such as fish and wetlands are therefore at similar level than currently.

Climate change is by 2040 visible both through **increased frequency of extreme weather events** and changed precipitation and temperature patterns, which also have an impact on Mekong water flows. While increased amount of storms and draught periods cause periodic challenges particularly to agriculture, all in all the general impacts from climate change are still relatively modest, although increasing.

Socio-economic development + migration

People who belonged to the so-called youth surge in 2012 have reached middle age, being 45-55 years old. Thanks to the government's successful health and birth spacing policies, the fertility rates have declined, meaning that the **family sizes are smaller** and the age groups born between 2012-2040 considerable smaller: this has reduced the dependency ratio as well. The younger age groups are also much better educated than in 2000s, with many young people completing high school: this change is partly thanks to government's active education policy. All in all, the **demographic dividend has worked well and it has –together with successful government policies and governance reforms– provided a window of opportunity to develop existing livelihoods as well as to create new ones.**

Migration from rural areas to urban areas has been balanced and moderate, being primarily initiated by 'urban pull' i.e. availability of decent work and housing in district towns and provincial capitals. At the same time, most people still stay at their home villages also in rural areas, getting their livelihoods from the largely agriculture-based activities.

Those migrating from rural areas to urban areas move usually permanently, and as a result the **urbanisation rate in the entire Tonle Sap is less than 50%.** The amount of urban areas has, however, grown: most district towns are now already cities, and several major villages have been turned into bustling towns. Many have migrated also to Phnom Penh or even abroad.

Livelihoods

Agriculture is still the most important livelihood source in the rural areas. Improved irrigation, more diverse crops and agricultural mechanization have led to **increased agricultural productivity**,

both per hectare and working hour. Rice is still the main crop, but also e.g. fruits, vegetables and different kinds of cereals and beans bring both income and food to the households.

Fishing is the main source of livelihood for people in Zone 1 (Lower Floodplain), and **fish remains as the main source of protein in Cambodia.** The government's efforts to promote sustainable resource use and equal access to aquatic resources (**fisheries reform)** have supported the development of fishing as the major livelihood source in rural areas. Majority of the current 200'000 ton fish catch comes from community cooperatives using large-scale fishing gears such as bagnets: cooperatives replaced the private fishing lots already in 2010s. Cooperatives are also running fish processing factories and fish markets, ensuring that majority of the benefits from fish stays with fishers.

Agricultural processing has in general developed remarkably, and all provincial capitals and most district towns have their own **food processing factories** that produce agricultural end products and different kinds of fish products. By-products and waste from food processing are used to create renewable energy. Half of the processed agricultural and fish products are exported, with other half going for domestic market. **Large-scale export brings plenty of foreign revenue,** enabling further investments to agricultural production and processing.

In urban areas the most important sources of employment include industry, service and construction. The **industry has agricultural and non-agricultural dimensions**, with agricultural industry focusing on agricultural and fish processing and trading.

Successful **implementation of environmental protection policies** –including Environmental Impact Assessment– means that the environmental impact of growing cities as well as different sectors (agriculture, industry etc.) has remained modest and pollution is under control. Cambodia has even profiled itself as **'sustainable manufacturer'** (both environmentally and socially). As a result, multinational companies are happy to have Cambodia –including Tonle Sap– as the supplier for their products, ranging from garment and shoes to mobile phones and computers. Siem Reap area is the main tourist destination of the entire country, including **ecotourism to Tonle Sap Lake**. In district cities and towns, agricultural industry is the main employee, with workers commuting also from the surrounding rural areas to work. The growing industry, service and construction sectors require increasing amount of work force, and as a result plenty of young people –usually those with highest education– have migrated permanently to cities and towns.

Remarks

Combination of developing existing main livelihoods (agriculture and fishing) as well as diversifying the livelihood base with new main livelihoods (industry, service, construction etc.) means that the Tonle Sap area has been able to make a **maximum use of the demographic dividend that started in 2010s,** decreasing the dependency ratio and increasing the amount of people in work force.

Livelihood development and diversification –particularly improved agricultural and fish processing and trading– has also meant that the Tonle Sap area is seeing increasing amount of export revenues. More money available means more investments to different sectors (agricultural and non-agricultural) as well as to infrastructure (physical infrastructure, education, health), which means both improved living standards and more income.

D) Tonle Sap in 2040: Stagnation

Tonle Sap flood pulse preserved, supporting high aquatic production

Under this 'alternative future', the Mekong dam building ceased in 2010s, and **large-scale hydropower was replaced by more decentralised energy production,** building on renewable energy such as solar, wind, biomass and micro-hydropower (see e.g. CRCD 2004, 2006; World Bank 2006; Ryder 2009; Toch 2010). Energy plans were also revised to focus on energy saving measures, leading to major slow down in the increase of energy consumption.

Without new large-scale dams since 2010, **water flows of the Mekong and Tonle Sap flood pulse are close to natural still in 2040.** Also influx of the nutrient-rich sediments from the Mekong to the Tonle Sap floodplain has been maintained. The water-dependent resources such as fish and wetlands are therefore at similar level than currently.

Climate change is by 2040 visible both through **increased frequency of extreme weather events** and changed precipitation and temperature patterns, which also have an impact on Mekong water flows. While increased amount of storms and draught periods cause periodic challenges particularly to agriculture, all in all the general impacts from climate change are still relatively modest, although increasing.

Socio-economic development + migration

People who belonged to the so-called youth surge in 2012 have reached middle age, being 45-55 years old. The fertility rates have declined, but are still rather high: family sizes particularly in rural areas remain large and as a result population keeps on growing. The education level has slowly improved, but there are considerable differences between urban and rural areas: most of the youth in rural areas complete still only primary school. All in all, the **government's policies on health, education and poverty reduction have been implemented with varying success,** and the situation in many rural areas is particularly challenging.

Migration from rural areas to urban areas has been rather considerable, being initiated both by 'urban pull' and 'rural push'. At the same time, **most people still stay at their home villages** also in rural areas, getting their livelihoods from the largely agricultural-based activities.

Those migrating move usually permanently, and as a result the urbanisation rate in the entire Tonle Sap is around 60%. The amount of urban areas has also grown: most district towns are now already cities, but many of them have also considerable slums accommodating rural migrants.

Livelihoods

Agriculture remains as the most important livelihood source in the rural areas. However, the lack of agricultural infrastructure and investments and the poor implementation of the government's agricultural policies means that the **agricultural production has not improved**. Due to population growth the agricultural production per capita has been reduced: as a result people's income levels have not really improved.

Fishing is the main source of livelihood for people living in Zone 1 (Lower Floodplain), and fish remains clearly as Cambodian's main source of protein. Yet, the fisheries reform hasn't really progressed as planned in 2010s, and a majority of the current 200'000 ton fish catch is caught with large-scale, private fishing gears. As a result, the **levels of livelihood for majority of fishers (i.e. small-scale fisher) haven't therefore been really improved**, and some have been migrating to the cities to search for other livelihood sources.

In urban areas the most important sources of employment are industry, service and construction sectors, but all of them have grown only slightly from the levels of 2010s. Given the **stagnant agricultural production, the industry is increasingly non-agricultural.** Lack of livelihood options in rural areas have led to migration to urban areas, but most of these people don't have job in urban areas either.

Remarks

Lack of investment and innovation in agricultural production as well in agricultural and fish processing means that the **stagnant livelihood structure** –that remains similar to that in 2010s– cannot anymore properly support the increasing population. Consequently, production per capita has decreased and the entire Tonle Sap area is not really developing, but rather in the state of stagnation and slow deterioration.

Four alternative futures: summary tables

In the previous pages, we provided a short description of all four alternative futures, focusing on the key aspects related to water-dependent resources (agriculture and fisheries), livelihoods and selected socio-economic factors (demography, migration, education).

In this chapter, we summarise the main characteristics of all four alternative futures with the help of two complementary tables. Table 7 includes the summaries of the four alternative futures as well as two 'water paths'. Table 8 focuses then on the key policy implications i.e. how the implementation and non-implementation of the policies has a major influence on how each alternative future eventually evolve. In this way, the two tables provide more detailed explanation of the four alternative futures and their drivers (water paths + societal development paths) described in Annex G.

Indeed, it is crucial to notice that while the Mekong hydropower development is likely to change the Tonle Sap system radically, both 'water paths' (i.e. plenty or only few Mekong dams) can lead to positive or rather negative development outcomes for the Tonle Sap. For the Tonle Sap development naturally depends first and foremost on how socio-economic situation and livelihoods develop in the area – and, hence, how government's social and livelihood policies are implemented. In this way, the future of the Tonle Sap is closely linked with the implementation of the government's policies in the Tonle Sap.

While it is impossible to foresee how successfully the current policies will actually be implemented in next 20-30 years, Table 8 seeks to summarise the main policy implications of the four alternative futures presented above. The policy implementation links naturally closely to the 'societal development paths' of each alternative future (see Annex G), and there are thus clear similarities between different alternative futures: the policy implications of Alternative Future A are similar with Alternative Future C (orange), and those of Alternative Future B similar with Alternative Future D (red).

Table 7. The main characteristics of the four alternative futures envisioned for the Tonle Sap in 2040.

	Hydrology, flood pulse & fisheries	Socio-economic changes + migration	Livelihoods	Remarks
A) 'Major changes'	'WATER PATH' 1: Intensive dam building in upper Mekong providing energy, but also leading to changes in flood pulse: radical reduction (-50%) in fish production. Agricultural land area slightly increased due to changes in flood-plain habitats.	Tonle Sap has benefited from 'youth surge' of 2010s, leading to livelihood development even when fisheries have decreased. Population growth ok, education levels improved. Migration rather balanced, but urbanisation over 60% as urban areas offer more livelihood options.	Agriculture's role has diminished, but remains important livelihood activity in rural areas. Agricultural productivity and food processing have improved remarkably, and new paddy area become available in the upper parts of the floodplain. Urban areas growing, with employment being increasingly non-agricultural.	With new livelihood developent, the dependency on agriculture and fisheries has reduced. Yet, food security remains a major challenge due to radical reduction in fisheries.
B) 'Growing disparity'		Many from 'youth surge' of 2010s didn't find meaning-ful livelihood sources. Population growth high, education levels low partic. in rural areas. Uncontrolled migration from rural to urban areas to search for work: 75% of people living in urban areas, but largely in vain: plenty of slums.	The role of fishing reduced dramatically. Agriculture still important, but productivity remains low: due to population growth production per capita has decreased. Farm sizes growing and agriculture concentrating to few hands. Urban areas not growing fast, either.	Rural livelihoods don't develop, leading to increasing disparity within and between urban and rural areas. Food security remains a major challenge due to radical reduction in fisheries.
C) 'Green growth'	'WATER PATH' 2: Thanks to increased energy efficiency and renewable energy production, no new dams were constructed after those started in early 2010s. Tonle Sap flood pulse is maintained and it continues to support high aquatic production.	Tonle Sap has benefited from 'youth surge' of 2010s, leading to livelihood development and diversity in both urban and rural areas. Population growth ok, education levels improved. Migration balanced, urbanisation less than 50% as rural areas have plenty of livelihood options as well.	Agriculture still most important livelihood, but role of fisheries remarkable too: fishing cooperatives distribute benefits to many. Agricultural productivity and food processing improved remarkably. Urban areas growing, with empolyment in both agricultural and non-agricultural sectors.	Livelihood development and diversfication has provided meaningful jobs for younger generation, and has led to progress that benefits both rural and urban areas. Rural and urban areas closely connected and benefiting from each other.
D) 'Stag-nation'		Many of 'youth surge' of 2010s didn't find meaningful livelihood sources. Population growth still quite high, education levels low particularly in rural areas. As livelihood opportunities in rural areas are poor, migration from rural to urban areas to search for work (urbanisation around 60%), but largely in vain.	Livelihood structure has stayed similar to 2010s, with agriculture dominating. Lack of livelihood development and diversification mean that production per capita has been reduced. Employment in urban areas largely non-agricultural, but not growing fast, either.	Lack of innovation and investments to livelihood development and diversification has led to decreased production in capita: state of stagnation and gradual deterioration.

Table 8. The policy implications of the four alternative futures. The table complements Table 7 by summarising the implementation and, importantly, non-implementation of the selected policies in the Tonle Sap area by 2040. For details, see the descriptions of the alternative futures above + Annex G. Note that Alternative Futures A and C (orange) + Alternative Futures B and D (red) are similar.

	Human resources development (education, health, population policy etc.)	**Livelihood diversification & job creation**	**Agricultural development, incl. fisheries**	**Environmental protection & sustainable natural resource use**
A) 'Major changes'	With solid tax revenues and good governance, government's social policies have worked well. Social safety net protecting the livelihoods of the poor established. With improved education and health levels and integrated population policies, population growth is moderate. With meaningful jobs also in rural areas, migration from rural to urban areas is balanced.	Government's policies have together with functioning markets and development of private sector (incl. SMEs) created plenty of new jobs for both agricultural and non-agricultural sectors. Cheap energy available from hydropower helps in this. Existing (largely agricultural) livelihoods diversified + new livelihoods created.	Agricultural productivity has enhanced considerably. Despite reducing fish catches, goverment's fisheries reform has enabled at least some small-scale fisher to maintain their livelihood levels. Food processing industry is booming, and 'one village-one product' movement has helped to diversify agricultural production in rural areas.	Environmental protection policies minimise the pollution and negative impacts caused by the industry and agriculture. Natural resources used in sustainable manner, with policies responsing effectively to the major changes in flood pulse and the related resources.
B) 'Growing disparity'	Government's social policies have been implemented with varying success, and there are great differences between rural and urban areas. Education levels remain rather low, and population growth is at 2.0%/year still rapid. As the livelihoods don't develop and fiscal policy is not implemented, also tax revenues remain modest: the government's social spending remains thus modest.	Government's policies have failed to provide meaningful jobs for the 'youth surge' of 2010s. Lack of livelihood diversification and poorly functioning markets mean that new livelihoods are being created only very slowly and to certain sectors (mainly private large-scale enterprises): some benefit, but majority of the people not.	Agricultural production has not really improved due to slow implementation of agricultural policies: per capita productivity has decreased due to population growth. Physical infrastructure (incl. irrigation) developing only slowly and mainly by few big land owners. Fisheries reform facing challenges, with fishing concentrating to few powerful large-scale fisher: small-scale fisher suffering greatly.	As environmental policies remain weakly implemented, the combination of population growth, lack of livelihoods and reducing availability of fish have led to major overexploitation of the remaining natural resources: e.g. Tonle Sap flooded forests lost. Pollution from the cities and the industry not under control either.
C) 'Green growth'	With solid tax revenues and good governance, government's social policies have worked well. Social safety net protecting the livelihoods of the poor established. With improved education and health levels and integrated population policies, population growth is moderate. With meaningful jobs also in rural areas, migration from rural to urban areas is balanced.	Government's policies have together with functioning markets and development of private sector (with focus on SMEs) created plenty of new jobs for both agricultural and non-agricultural sectors. Food processing industry booming, and its by-products are used for renewable energy. Renewable energy development helping the livelihood development, and also creating plenty of new jobs.	Agricultural productivity has enhanced considerably. Goverment's fisheries reform has enabled small-scale fisher to maintain reasonable livelihood levels. Food processing industry is booming in the cities, and 'one village-one product' movement has helped to diversify agricultural production in rural areas.	Environmental protection policies minimise the pollution and negative impacts caused by the industry and agriculture. Effective implementation of Environmental Impact Assessment has helped to change several development projects towards more sustainable direction.
D) 'Stag-nation'	Government's social policies have been implemented with varying success, and there are great differences between rural and urban areas. Education levels remain rather low, and population growth is at 2.0%/year still rapid. As the livelihoods don't develop and fiscal policy is not implemented, also tax revenues remain modest: the government's social spending remains thus modest.	Government's policies have failed to provide meaningful jobs for the 'youth surge' of 2010s. Due to challenges with the functioning of the markets and private sector development, new livelihoods are being created only very slowly.	Agricultural production has not improved due to population growth + slow implementation of agricultural policies. Physical infrastructure (incl. irrigation) developing only slowly. Fisheries reform facing challenges, with fishing concentrating to few powerful large-scale fisher: small-scale fisher suffering greatly.	Environmental policies remain weakly implemented. As a result, the combination of population growth and lack of livelihoods have led to overexploitation of the remaining natural resources. Pollution from the cities and the industry not under control either.

‘Surprise factors‘

The four alternative futures above have described possible development trajectories that can follow from the transformations we expect to happen in the Tonle Sap area based on the changes in water flows as well as on the current socio-economic and livelihood trends and the related policies. As discussed above, the alternative futures build on our modelling estimates and trend analyses and do not include major surprises or irregularities. Yet, different kinds of surprises and non-linear developments are always reality, and they are likely to impact significantly the development of the Tonle Sap.

For this reason, we want in this chapter to introduce three additional changes that are not as easy to forecast or even foresee, but that are nevertheless considered possible to occur in the Tonle Sap area within next 30 years. Most importantly, if they would occur as imagined below, they are likely to have a major influence on the development of the Tonle Sap area. In other word, they are low-probability, high-impact events that can be called ‘surprise factors’ or ‘wild cards’ (see e.g. van Notten et al. 2005; Mahmoud et al. 2009; Heikinheimo 2011). Such surprise factors can be seen to come on top of our four alternative futures, changing their dynamics and having potentially very significant –positive or negative– impact on how they eventually evolve.

While the three surprise factors described below are naturally a source of imagination, they have their foundation on actual research and strategies (see relevant references under each sub-chapter). The themes of the surprise factors are based on the ideas and comments provided by the workshop participants in the series of Tonle Sap scenario workshops (see also scenario narratives in Foran et al. 2011), complemented by our own brainstorming. Similarly to the four alternative futures, the three surprise factors are future-orientated, and are thus written in present tense but as if they would occur in the future (e.g. in year 2015).

Intensive oil and gas extraction in the Tonle Sap

In this ‘surprise factor’, it is assumed that the intensive explorations carried out by private petroleum companies in partnership with Cambodian National Petroleum Authority (see e.g. Vichit 2010) expose in year 2015 huge oil reserves in the Western parts of the Tonle Sap floodplain. Given the huge economic benefits that such reserves are anticipated to bring, oil drilling in the floodplain start already in 2018.

Despite advanced environmental impact assessment as well as safety and mitigation measures, the drilling causes periodic oil spills that severely harm the Tonle Sap ecosystem, including fish and birds. One of the biodiversity conservation areas of the lake (Prek Toal) gets badly polluted, and the availability of the fish in the floodplains is reduced. As a result, ecotourism and fishing sectors suffer severe losses, and many lose their livelihood sources. On the other hand, the economic gains from the drilling are substantial, and the sector also employs hundreds of people for differing tasks.

Tonle Sap algae for renewable energy

In this 'surprise factor', it is assumed that the studies carried out by the Institute of Technology of Cambodia reveal in 2016 that the Tonle Sap has a special species of algae that is exceptionally well suitable for biofuel production (see e.g. Campbell et al. 2006; Demirbas 2011).

As a result, large areas of the lake are allocated for algae production, and the Tonle Sap becomes the biofuel hub of the Mekong. The 'Tonle Sap bio-algae' is transported for biofuel plants around Cambodia and also exported to Thailand, Vietnam, China and even to Europe and US. As the plants require intensive maintenance, the bio-algae industry –including both private companies and village cooperatives– provides source of livelihoods for thousands of people.

Southeast Asia's prime ecotourism destination

In this 'surprise factor', it is assumed that that the government's efforts to promote ecotourism (e.g. Thok 2011) are leading the amount of tourists visiting the Tonle Sap Lake to increase dramatically from year 2012 onwards. In 2020, there are already one million tourists visiting the different parts of the lake and floodplain, making the Tonle Sap the most popular ecotourism destination in Southeast Asia.

While majority of the tourists visit the lake with a daytrip from Siem Reap, the three-day Tonle Sap Lake tours taking tourists down to the lake delta in Chhnok Tru and including overnight stays in the floating houses are attracting more and more people. In addition, there are specialised tours including e.g. fishing trips, bird watching and kayaking. Such tours also distribute the profits from the tourism more equally, as increasing number of villages is able to provide tourists with accommodation and other services (restaurants, souvenirs etc.). As a result, the Zone 1 closest to the lake has been transformed into 'Tourism Zone'.

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PART 4: CONCLUSIONS

KEY FINDINGS RELATED TO WATER AND PEOPLE

- Tonle Sap is a hydrologically, environmentally and socio-culturally unique system, also globally. It has remarkable social and economic importance to Cambodia, as it presents source of livelihood and food security for millions of Cambodians. Yet, it is also very vulnerable to the changes caused by the Mekong hydropower plans.
- Agriculture dominates the livelihood activities in the Tonle Sap area: it is together with fishing the basis for national food security. Fishing forms critical livelihood source close to the lake, while in urban areas the livelihood sources are much more mixed.
- All in all, there are major socio-economic and livelihood differences between the different areas of the Tonle Sap, with Siem Reap and its service sector standing out.

POSSIBILITIES TO INFLUENCE NOW: REGIONAL, NATIONAL, LOCAL

- Cambodian government has major role for the development of the Tonle Sap area. At **regional level**, the government should continue active discussions on the most sustainable ways to develop the Mekong's water resources, including hydropower.
- At **national level**, the Cambodia's Rectangular Strategy incorporates all relevant policies needed for the positive transformations to occur in the Tonle Sap. However, putting these ambitious policies into practice is not easy and requires major attention.
- At **local level,** it will be important to consider the differences in the current status and future development potential within the Tonle Sap area itself. While the three zones (Lower Floodplain, Upper Floodplains, Urban) are generally rather homogeneous entities, there are also major differences between the 18 sub-zones of this study.
- In agriculture, increasing the agricultural productivity will be particularly important. We also suggest that the provincial capitals could be developed in bit different ways, building on their existing –and partly differing– strengths. In Zone 1 (Lower Floodplain), successful implementation of the on-going fisheries reform will be a critical component for the livelihood development. Major efforts are also needed to ensure improvements in general human resources development, including health and education.

CONCLUDING REMARKS: WATER-ENERGY-FOOD NEXUS

- The social and economic development of the Tonle Sap has close linkages to land and natural resources and, more broadly, to the so-called water-energy-food nexus.
- Successful development of the Tonle Sap asks for active cross-sectoral collaboration between the agencies implementing the relevant policies at different levels.

Key findings related to water and people

The Tonle Sap Lake area forms a **critically important economic, social and environmental resource for entire Cambodia.** The Tonle Sap flood pulse is the driving force of the entire lake-floodplain system –including its immense fisheries–, and it also makes the area globally unique hydrologically, environmentally as well as socio-culturally.

The Tonle Sap flood pulse is, however, likely to change in the future as a consequence of anthropogenic impacts, particularly through intensive hydropower development in the Mekong River Basin. In fact, the **Tonle Sap Lake area can be considered as the most vulnerable area to the changes caused by the current hydropower plans in the Mekong**[18]. At the same time, there are also variety of local development plans in the Tonle Sap basin and floodplain, ranging from large-scale irrigation structures to hydropower development in the Tonle Sap tributary rivers. In addition, climate change is estimated to cause changes to the lake-floodplain system, although the exact nature and even the direction of these changes remains unclear due to major uncertainties included in the climate estimates. Within the timeframe of our study (by year 2040), **the planned hydropower development in the Mekong is expected to have much greater impact on the Tonle Sap flood pulse than climate change.**

The possible changes in flood pulse include increased dry season water levels and decreased wet season water levels, leading to a reduction in the annually flooded area. Dams will also reduce the inflow of nutrient-rich sediments to the Tonle Sap and block fish migration routes. In aggregate, these changes are expected to **radically reduce the ecosystem productivity of the lake-floodplain system, with a potential for the Tonle Sap fish production to go down by 50% or even more.**

In sum, we foresee that the most remarkable socio-economic and livelihood impacts caused by Mekong hydropower development are related to the following three, interlinked themes. Firstly, the expected shifts in floodplain habitats can be potentially very destructive for existing floodplain ecosystems, impacting negatively fish production and therefore fishing. Yet, they can also lead to modest increase in agricultural areas in the upper floodplain, thus enabling potential increase in agricultural productivity and benefiting people living in Zone 2 (Upper Floodplain). Secondly, increased dry season water levels are expected to lead to the destruction of the majority of the remaining tall gallery forests ('flooded forests') surrounding the lake, having a major impact on sedimentation processes, ecosystems as well as on aquatic productivity[19]. It would also change the nature of environmental conservation and, hence, ecotourism, as large parts of the current conservational core areas would be permanently submerged. Thirdly and most importantly, the expected radical reduction in fish production will have major negative implications to livelihoods and food security of the Tonle Sap and entire Cambodia, with people in Zone 1 (Lower Floodplain)

[18] See also e.g. MRC (2010) or Hall & Bouapao (2010). The latter is a study done for the MRC, concluding that people living in Cambodia / Tonle Sap are (out of the four Lower Mekong countries) the most vulnerable in terms of baseline vulnerability, exceptionally deeply dependent on fish, and have very low resilience to major environmental (and other) changes.

[19] The dry season water level would also have some positive impacts, as it would increase the possibilities for dry season navigation in the lake. However, given that there is currently very little larger vessels navigating in the Tonle Sap and that majority of the transport happens anyway on National Roads, this impact is rather negligible.

being naturally most affected. Given the critical role that fish has for Cambodian food security, there is no easy way to solve this issue: addressing this question would therefore be of national importance and would require radical measures in improving other aspects of food production. Such radical changes require naturally also major resilience –or adaptive capacity– from the people living in the Tonle Sap, in particular from those involved in fishing and related activities. Worryingly, however, it seems that the people's capacity to adapt to unusual environmental changes is weak, with the poorest being clearly the most vulnerable group (Nuorteva 2009; Nuorteva et al. 2010: see also Marschke & Berkes 2006). Enhancing the resilience of the Tonle Sap people towards unusual environmental changes should therefore be considered in all development strategies.

In terms of socio-economy, close to 2 million people live in the lake and its floodplains, while up to half of Cambodia's population is estimated to benefit directly or indirectly from the lake's resources in terms of livelihoods and food security. Population in the Tonle Sap area keeps on growing. In addition, the Tonle Sap is –consistent with the rest of Cambodia– **experiencing exceptionally large age groups of young people born in the 1990s entering into the work force: we call this 'youth surge'.** Given the dominance of agriculture and the already heavy pressure on the area's natural resources, the **Tonle Sap's future depends very much on what kinds of livelihood sources these young people will, and are able to, move to** – as also noted by the Cambodian Government (RGC 2010). The 'youth surge' provides a possibility for demographic dividend, where the increase in work force and the related reduction in dependency ratio provide a major boost for the development of the area: this requires, however, meaningful work opportunities.

The livelihood structure of the Tonle Sap area remains dominated by agriculture, with over 60% of the total work force i.e. around **one million people having agriculture as their main source of livelihood**. Agriculture seems slowly be developing, as indicated for example by the increasing amount of irrigated land plots. The proportion of fishing is at 4.5% (according to Census 2008) much less than that of agriculture, but our study confirms the finding that fishing forms an important additional source of income and food for many other people as well. In addition, the role of fish for the food security of the entire country is very critical.

There are **signs of increasing livelihood diversification,** with more and more people transferring from traditional, agriculture-based livelihoods to more modern sources of income, including industry, service and construction sectors. This also means that the provincial capitals and district towns are attracting migrants (seasonal and permanent) from the rural areas. Yet, the findings of the CSIRO Tonle Sap Household Survey 2011 indicate that **people are in general not very willing to move**, but would prefer to stay in their home villages and maintain their current livelihoods.

The Tonle Sap area is developing unevenly, and substantial differences are visible both between different provinces as well as between the three zones used in the study: the Zone 1 (Lower Floodplain), the Zone 2 (Upper Floodplain) and the Zone 3 (Urban). Worryingly, the **disparities between the rural and urban areas seem to be increasing** in several well-being factors such as education. There are also clear differences in the 18 sub-zones included in this study, emphasising the importance to study the area at sufficient level of detail. Most notably, the **Urban sub-zone of Siem Reap has –largely thanks to its booming tourism sector– been developing very differently to other urban areas**: this development is also reflected in the development of Siem Reap sub-zone 2.

Possibilities to influence: regional, national, local

The **future of the Tonle Sap area includes many uncertainties**, and depends on both external driving forces –most importantly Mekong hydropower– as well as on internal changes in the socio-economic setting and livelihood structure of the area. Importantly, however, the **Cambodian Government has possibilities to reduce the uncertainties** and negative implications included in the future development of the Tonle Sap at regional, national and local levels.

While the Mekong hydropower development is a regional issue and depends therefore greatly on the decisions made by the governments of other Mekong countries, **Cambodia can actively contribute to the discussion about sustainable hydropower development through regional organisations** such as the Mekong River Commission (MRC) and Greater Mekong Subregion (GMS) Program. Cambodia has been increasingly active at both of these organisations, and for a good reason: the impacts that Mekong hydropower development will cause to the Tonle Sap and particularly its immense fisheries are likely to be major, possibly undermining the food security of the entire country. Given the severity of the situation, there is thus room for even more active regional involvement.

At national level, the implementation of the Government's strategic development plans (RCG 2010) is the key for the future of the Tonle Sap. At general level, we see that **Cambodia's Rectangular Strategy incorporates all relevant policies that are needed for the positive transformations to occur in the Tonle Sap within next 10-30 years.** Such policies include human resource development (education, health, gender) with focus on the poorest, active population policy, agricultural development, livelihood diversification and job creation, development of the physical infrastructure as well as sustainable use of the environment and natural resources. **Putting these ambitious policies into practice is not, however, easily done and requires major attention.** Their successful implementation requires participatory planning processes, close collaboration between different sectors and administrative levels and, in general, good governance.

At local level it will be important to **consider the differences in the current status and future development potential within the Tonle Sap area itself**. Our study confirms that the Tonle Sap area can be divided into three distinct 'resource use zones' or 'livelihood zones': Zone 1 (Lower Floodplain with fishing as main involvement), Zone 2 (Upper Floodplain with agriculture as main involvement) and Urban Zone. The livelihood structures in these zones are very different and have also stayed rather stabile within the past decade (1998-2008). Such a finding indicates that any **livelihood development in the Tonle Sap area should use the existing livelihood structure as a basis, building on and extending from it.** On the other hand, the vast amount of people entering the work force due to the 'youth surge' suggest that there are also needs for completely new kinds income sources: these are likely to be largely non-agricultural and be mainly developing to the cities and provincial towns.

The analysis of the 18 sub-zones shows, however, that there are differences also within each zone: this is most likely related to the differing socio-economic and governance settings in different

provinces as well as other issues such as accessibility and existing infrastructure[20]. Similarly, the different zones and sub-zones will also be very differently impacted by the expected changes in flood pulse, with most radical changes occurring in Zone 1 (due to possible reduction in fisheries) as well as in selected parts in Zone 2 in upper floodplain (due to possible changes in habitats).

Given that a great majority of the people are living in Zone 2 (Upper Floodplain), this zone will naturally draw a specific attention by the ministries and provincial authorities. **We suggest that the development of the Zone 2 and its sub-zones should build on existing livelihoods, with a particular focus on enhancing the agricultural productivity and improving the access to the markets.** Agricultural productivity can be done in many ways, such as improving the use of the current agricultural lands (irrigation, new crop varieties etc.) as well as extending the area of agricultural land, where environmentally and socially feasible. Due to rapidly growing population, however, also the rural areas need to find alternative sources of livelihoods: in this the role of the private sector –including small and medium size enterprises SMES– is likely to be significant.

At the same time, the Zone 1 (Lower Floodplain) and Zone 3 (Urban) are socially and economically very critical areas, although for very different reasons: **urban areas act the engines of change for the entire area, while the people living in Zone 1 (Lower Floodplain) are in many ways in the most vulnerable situation; not least because of expected changes in the Tonle Sap flood pulse.**

Both of these areas require therefore also major attention by the central government and provincial authorities. Given how differently the urban areas seem to develop, it could possibly be useful to make use of the differences and **develop provincial capitals in bit different ways**. While Siem Reap is the obvious tourism and service center of the entire area, other provincial capitals could focus on improving non-agricultural and/or agricultural industries, making use of their location (close to Thailand, Phnom Penh etc.), the resources of their surrounding rural areas (agricultural products, other natural resources etc.) as well as the availability of labour. Given that the urban areas attract plenty of educated people and have good infrastructure and market connections, the **possibilities for creating new income sources and job opportunities** –including establishment of different kinds of SMEs– in the urban areas are remarkable as well.

In Zone 1 closest to the lake, the key will be to ensure that the on-going fisheries reform is implemented in equitable and sustainable manner, so that it benefits all the fisher (with focus on small-scale fisher) and at the same time does not lead to overexploitation of the fish stock. Establishing some kinds of community cooperatives to replace the private fishing lots could be one feasible option to ensure this. Such cooperatives could also develop fish processing facilities, so that increasing amount of the benefits stays in the zone. Given the poor socio-economic conditions in the Zone 1 (Lower Floodplain), the provincial authorities should also pay a special attention for the implementation of their human resources development policies (incl. education, health) in the area.

[20] On the other hand, the CNMC's Tonle Sap Sub-area report shows that there are major differences also between the socio-economic and livelihoods characteristics of 12 main secondary basins in the Tonle Sap Basin (Annex C). This seems to indicate that the differences are not only linked with socio-economic issues, but also e.g. with differing environmental characteristics.

Concluding remarks: water-energy-food nexus

The four alternative futures for the Tonle Sap in 2040 we created seek to provide a perspective on the possible future paths that the Tonle Sap area may experience. While the basic setting depends on external driving forces such as Mekong hydropower development, the alternative futures also indicate that the future development of the Tonle Sap depends very much about the way the area's socio-economic setting and livelihoods are evolving in next few decades. In this, the policies and governance structure applied by the central government and provincial and district authorities assume a primary role: the government's National Strategic Development Plan Update lists several important objectives that, we believe, strongly promote the development of the Tonle Sap area.

In addition, the Cambodian government has a major role in opening up the regional discussion about the ways to develop the Mekong, including hydropower dams and their cumulative impacts. The government can also contribute –positively or negatively– to the occurrence of so-called surprise factors that can potentially change the future of the Tonle Sap even more dramatically than what we suggest in the four alternative futures. Consequently, **it is ultimately the Cambodian government that provides the area with necessary means for social and economic development as well as the capacity to adapt and response to the upcoming environmental changes.**

The findings from our study indicate that the social and economic development of the Tonle Sap has close linkages to land and natural resources and, more broadly, to the so-called water-energy-food nexus – or in our case **water-energy-food-climate nexus**. Water is also in many ways the connecting factor between these different themes. The connections are being characterised by a very interesting dualism: **water simultaneously enables and is impacted by energy production and food production.**

The situation is similar in terms of climate change: water has close linkages with climate change mitigation as majority of the world's renewable energy production –dominated by hydropower and bioenergy– is directly linked with water (Varis 2007). At the same time, water also connects closely with climate change adaptation as majority of the climate change's impacts to societies –e.g. floods, droughts and extreme weather events– are felt through the changes occurring in hydrological cycle (e.g. Keskinen et al. 2010).

Worryingly, the energy and food production sectors seem not always to be considering the impacts they cause to water and the related resources. The water-energy-food-climate nexus has also strongly spatial dimension, as the decisions related to energy production are done at very different level (i.e. Mekong-wide), compared to the level (i.e. Tonle Sap) where the food security- and livelihoods-related impacts caused by such decisions are occurring.

At the same time, water has close linkages with various different sectors (agriculture, fishing, energy, environment…) at both national and local levels. Consequently, it is obvious that the government's policies –related e.g. to fishing, agriculture and irrigation, food markets, hydropower and the environment– should not be implemented in isolation, but there must be **active cross-sectoral collaboration between different agencies when implementing the relevant policies at the different levels in the Tonle Sap**. Such collaboration is particularly important when noting that the

development objectives of the different sectors –including Cambodia's Rectangular Strategy– are not always complementary, but can actually be counter-productive to each other (e.g. rapid industrial development may lead to negative impacts to agricultural lands, or increase in agricultural productivity into environmental pollution). The cross-sectoral collaboration should therefore build on integrated, holistic view on the development of the area, and is likely to require continuous discussions and deliberations as well as negotiated trade-offs between different ministries.

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ANNEXES

ANNEX A. Draft map comparing our three zones with official ‘Protection zones’

ANNEX B. Tonle Sap Basin area, including 12 main secondary basins

ANNEX C. Commune Database 2008: key characteristics in the Tonle Sap Basin

ANNEX D. Census: people having agriculture, hunting or forestry as their main livelihood source

ANNEX E. Census: people having fishing as their main livelihood source

ANNEX F. Census: selected indicators grouped according to gender

ANNEX G. Four alternative futures and their drivers (dams + societal development)

ANNEX H. Changes in flood pulse characteristics

ANNEX I. Excerpts from National Strategic Development Plan Update

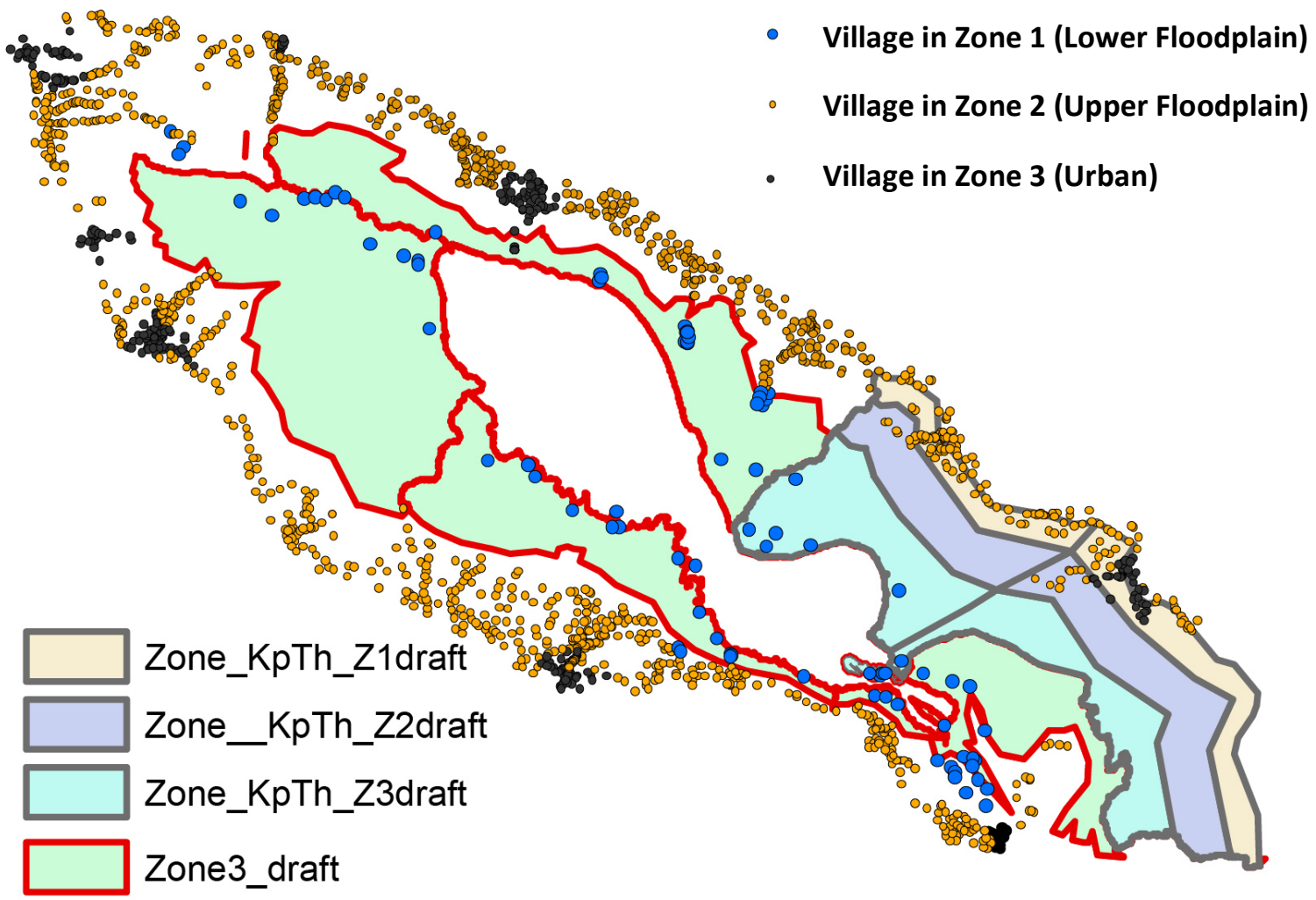
ANNEX J. Local water development in the Tonle Sap Basin

ANNEX A. Draft map comparing our three zones with official 'Protection zones'

Cambodian government has defined three official 'Protection zones' that are used to define the limitations to the natural resources use in the Tonle Sap area. They are thus clearly different to the three zones used in our study (see e.g. Annex D). For clarity, the numbering of the zones is different as well: while our Zone 1 is closest to the lake, the Protection zones are numbered so that Protection zone 3 is closest to the lake.

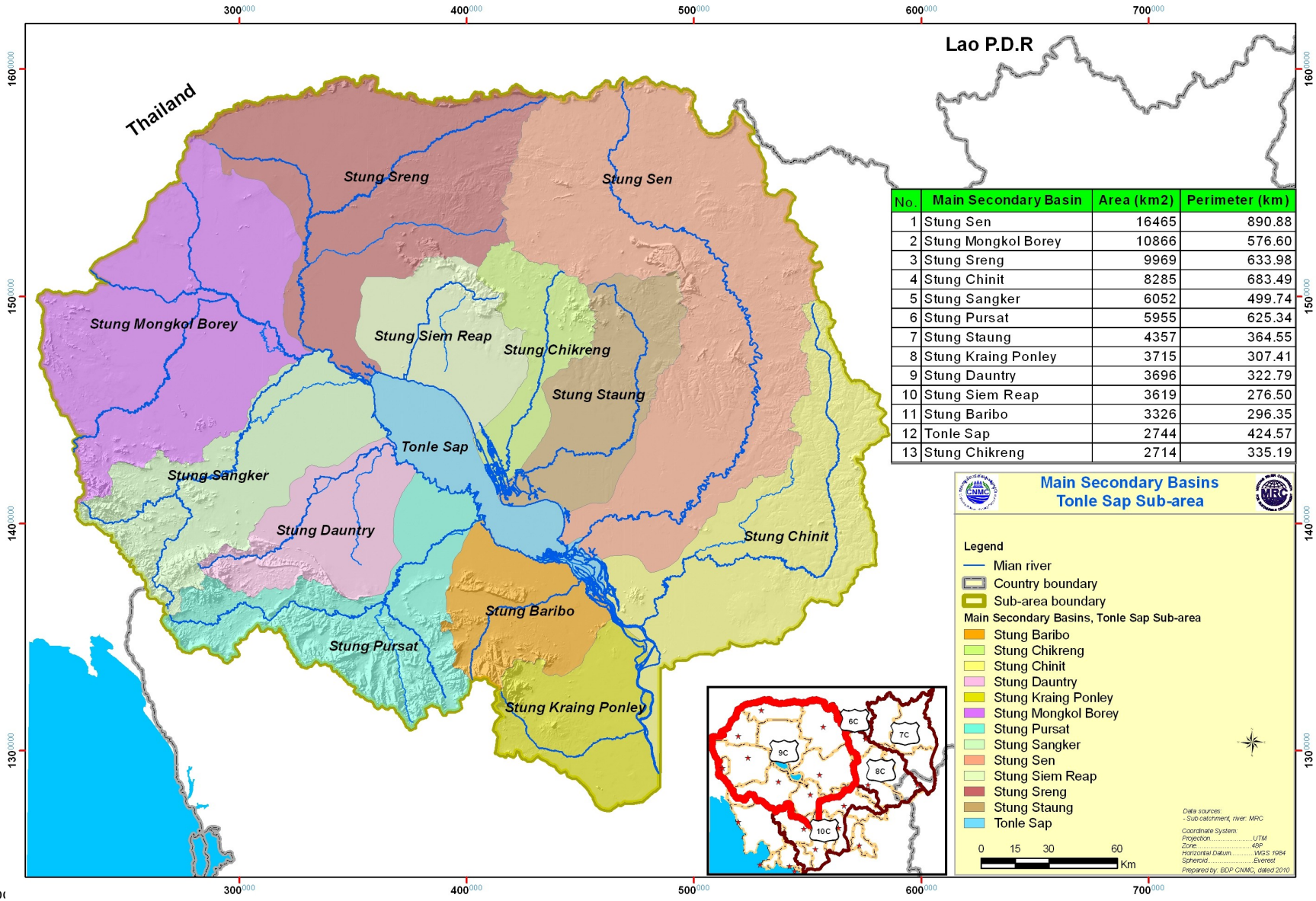
There is currently no clear spatial data on the government's Protection zones. Consequently, the attached map shows only the draft borders of the three Protection zones for the Kampong Thom, together with draft border for Protection zone 3 in the entire Tonle Sap area (light green with red border).

As can be seen, the official Protection zone 3 corresponds quite closely with our Zone 1 (blue villages), while Protection zones 2 and 1 (light blue and red, respectively) are then located either in our Zone 2 or Zone 3 (yellow and black villages).



ANNEX B. Tonle Sap Basin area, including 12 main secondary basins as well as the lake area.

Source: CNMC's Tonle Sap Sub-area Report (Mak et al. 2012).



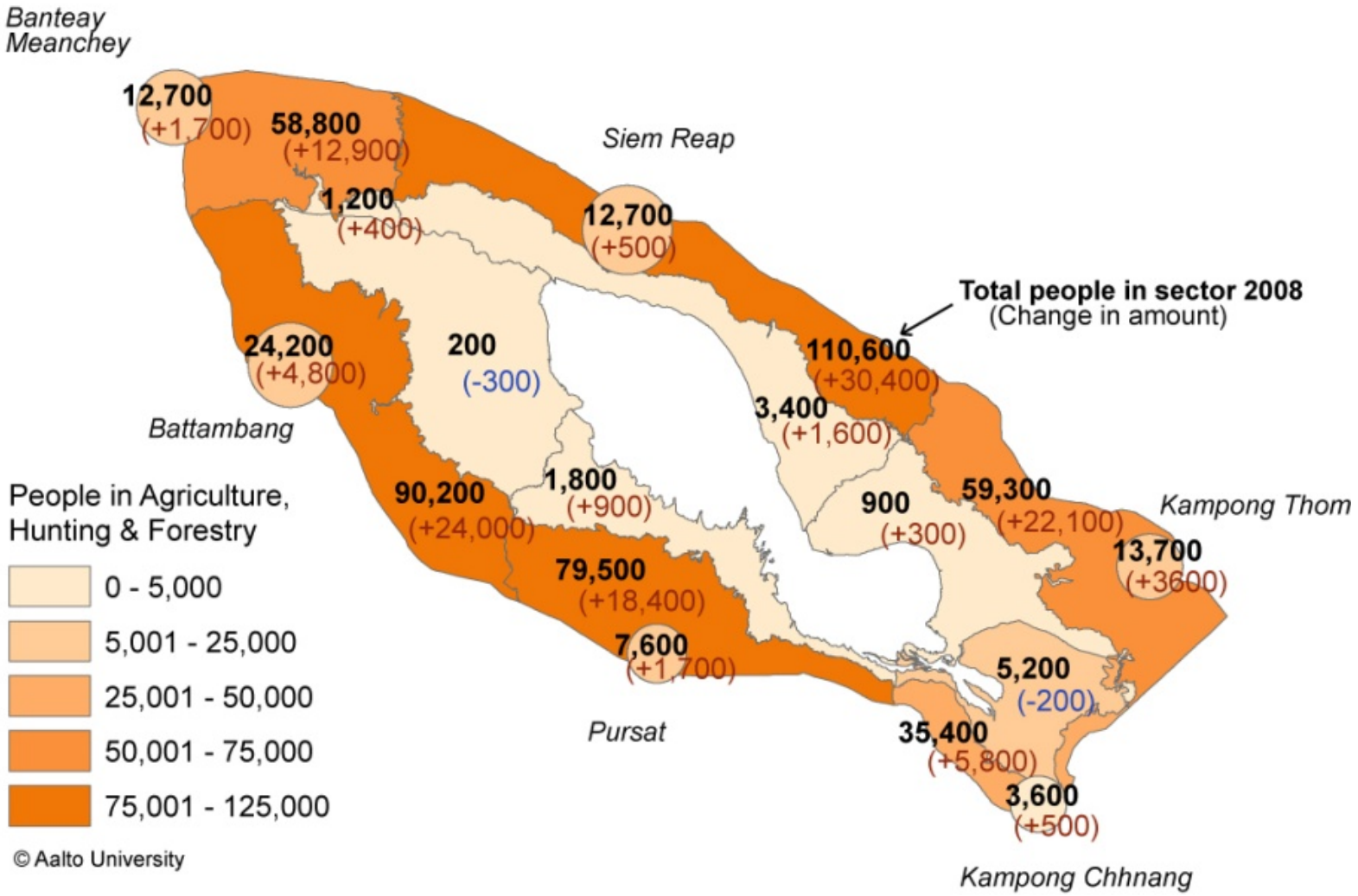
No.	Main Secondary Basin	Area (km2)	Perimeter (km)
1	Stung Sen	16465	890.88
2	Stung Mongkol Borey	10866	576.60
3	Stung Sreng	9969	633.98
4	Stung Chinit	8285	683.49
5	Stung Sangker	6052	499.74
6	Stung Pursat	5955	625.34
7	Stung Staung	4357	364.55
8	Stung Kraing Ponley	3715	307.41
9	Stung Dauntry	3696	322.79
10	Stung Siem Reap	3619	276.50
11	Stung Baribo	3326	296.35
12	Tonle Sap	2744	424.57
13	Stung Chikreng	2714	335.19

ANNEX C. Commune Database 2008: key characteristics in the Tonle Sap Basin

Table below summarises key socio-economic and occupational characteristics of the 12 main secondary basins and the lake area, forming the Tonle Sap Basin (Annex B). Compiled from the CNMC's Tonle Sap Sub-area Report (Mak et al. 2012). For comparison, see Table 1 and Table 2.

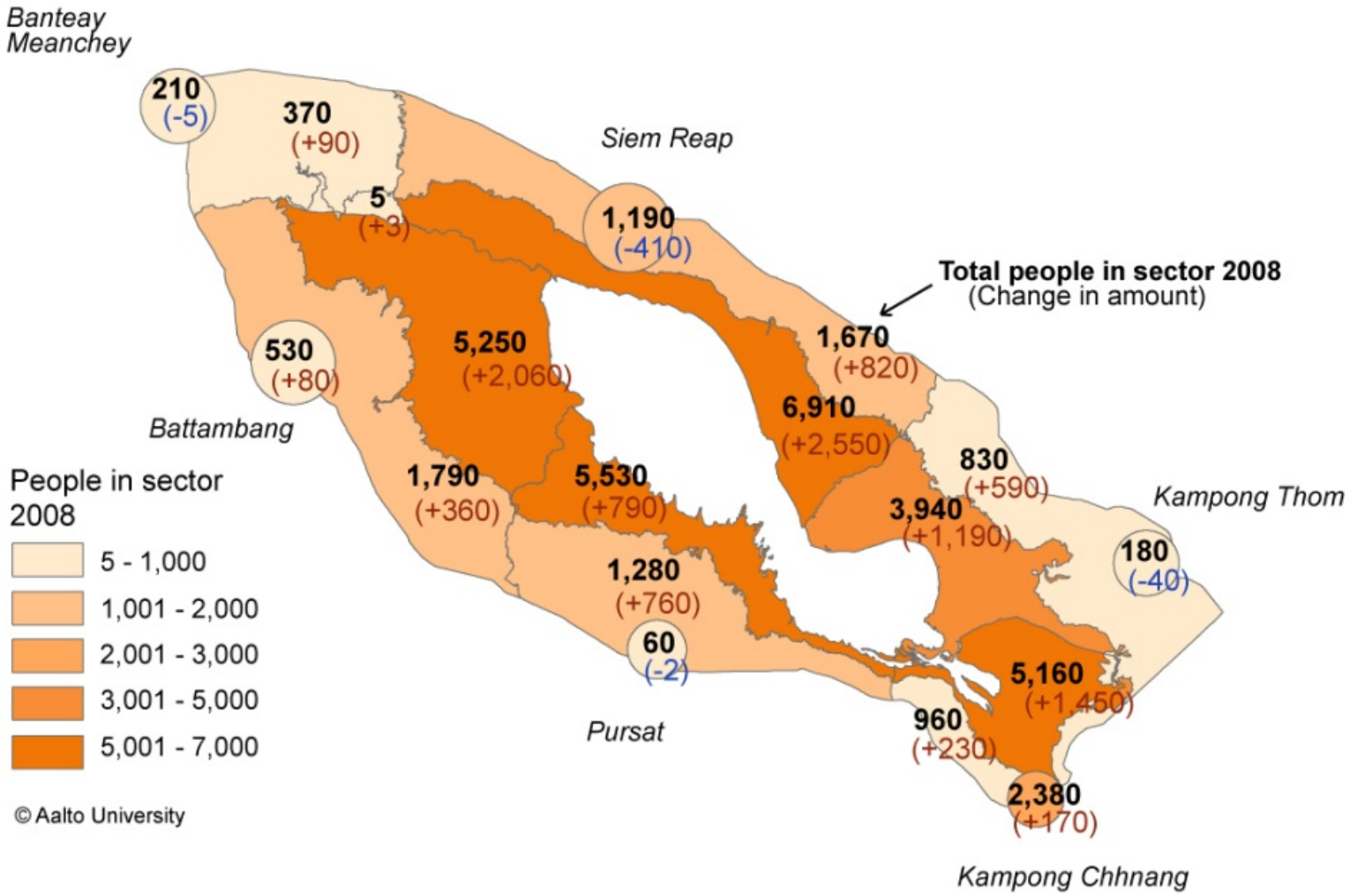
COMMUNE DATABASE 2008	Stung Baribo	Stung Chikreng	Stung Chinit	Stung Dauntry	Stung Kraing Ponley	Stung Mongkol Borey	Stung Pursat	Stung Sangker	Stung Sen	Stung Siem Reap	Stung Sreng	Stung Staung	Tonle Sap Lake Area	Tonle Sap Basin
Population	**179 622**	**109 334**	**541 511**	**260 368**	**595 938**	**1 045 964**	**203 522**	**436 316**	**367 098**	**509 922**	**402 005**	**182 909**	**24 039**	**4 858 548**
% of total population	3.7%	2.3%	11.1%	5.4%	12.3%	21.5%	4.2%	9.0%	7.6%	10.5%	8.3%	3.8%	0.5%	100.0%
Families / households	**37 970**	**19 983**	**109 679**	**51 388**	**119 195**	**205 309**	**39 377**	**84 547**	**75 492**	**93 600**	**80 348**	**35 348**	**4 060**	**956 296**
% of total households	*4.0%*	*2.1%*	*11.5%*	*5.4%*	*12.5%*	*21.5%*	*4.1%*	*8.8%*	*7.9%*	*9.8%*	*8.4%*	*3.7%*	*0.4%*	*100.0%*
Population growth rate / year	**0.8%**	**3.2%**	**0.2%**	**0.9%**	**1.1%**	**0.8%**	**0.8%**	**3.1%**	**1.3%**	**3.5%**	**3.1%**	**3.6%**	**2.1%**	**1.3%**
Dependency ratio	**73%**	**81%**	**74%**	**78%**	**71%**	**65%**	**75%**	**69%**	**75%**	**68%**	**66%**	**73%**	**83%**	**70%**
Proportion of poor population	**28.1%**	**26.3%**	**35.7%**	**33.5%**	**26.9%**	**32.5%**	**31.2%**	**25.8%**	**37.2%**	**24.8%**	**35.8%**	**33.8%**	**28.1%**	**31.1%**
People with chronic food shortage	**3.5%**	**3.2%**	**3.7%**	**3.5%**	**3.6%**	**3.5%**	**3.7%**	**2.8%**	**4.1%**	**2.8%**	**4.2%**	**3.9%**	**2.9%**	**3.5%**
Access to education	**68.3%**	**62.8%**	**68.6%**	**64.9%**	**71.4%**	**62.6%**	**68.1%**	**73.5%**	**68.2%**	**72.9%**	**63.4%**	**59.3%**	**43.4%**	**67.2%**
Illiteracy rate	**16.8%**	**23.9%**	**21.0%**	**17.6%**	**10.0%**	**14.8%**	**14.7%**	**14.5%**	**29.0%**	**18.5%**	**35.6%**	**37.5%**	**35.3%**	**19.4%**
Access to electricity	**7.4%**	**7.2%**	**12.1%**	**7.0%**	**17.3%**	**23.4%**	**22.1%**	**28.0%**	**10.3%**	**27.2%**	**9.1%**	**3.8%**	**1.1%**	**17.2%**
PRIMARY OCCUPATIONS BY HHs														
Rice farmer households (HHs)	**84.6%**	**84.2%**	**70.2%**	**87.1%**	**78.5%**	**64.8%**	**78.0%**	**51.3%**	**85.5%**	**63.9%**	**89.5%**	**91.0%**	**1.6%**	**73.2%**
Cash crop farmer households	**2.2%**	**1.3%**	**8.0%**	**1.3%**	**1.0%**	**15.4%**	**1.0%**	**13.9%**	**2.3%**	**1.6%**	**0.6%**	**0.8%**	**15.4%**	**6.3%**
Government officers	**4.8%**	**2.9%**	**3.6%**	**2.9%**	**5.4%**	**6.0%**	**8.3%**	**9.1%**	**7.3%**	**7.8%**	**5.3%**	**1.9%**	**1.5%**	**5.8%**
Private sector workers/officers	**4.1%**	**1.3%**	**9.6%**	**2.9%**	**12.5%**	**2.3%**	**3.9%**	**4.2%**	**4.2%**	**8.1%**	**1.4%**	**4.9%**	**2.1%**	**5.5%**
Traders	**2.8%**	**2.6%**	**2.7%**	**2.0%**	**3.7%**	**3.3%**	**4.6%**	**4.5%**	**2.2%**	**9.2%**	**2.1%**	**1.6%**	**3.1%**	**3.7%**
Other service providers	**2.0%**	**0.8%**	**4.1%**	**0.8%**	**2.3%**	**3.9%**	**4.5%**	**4.9%**	**0.9%**	**11.3%**	**1.2%**	**0.2%**	**0.4%**	**3.6%**
Fishermen	**3.5%**	**2.3%**	**1.2%**	**1.2%**	**1.1%**	**0.6%**	**1.2%**	**3.7%**	**0.5%**	**3.7%**	**1.1%**	**1.5%**	**75.0%**	**1.9%**
Transportation service providers	**0.4%**	**0.4%**	**0.7%**	**0.3%**	**1.0%**	**0.7%**	**0.8%**	**1.1%**	**0.5%**	**3.2%**	**0.2%**	**0.2%**	**0.3%**	**0.9%**
Vegetable farmer households	**0.7%**	**0.5%**	**1.2%**	**0.5%**	**0.4%**	**0.9%**	**1.0%**	**1.9%**	**0.3%**	**0.9%**	**0.2%**	**0.3%**	**1.3%**	**0.8%**
Livestock farmer households	**0.3%**	**0.2%**	**0.6%**	**0.1%**	**0.3%**	**0.3%**	**0.5%**	**0.7%**	**0.1%**	**0.5%**	**0.1%**	**0.1%**	**1.2%**	**0.3%**
NTFP collectors	**0.3%**	**0.1%**	**0.1%**	**0.0%**	**0.1%**	**0.0%**	**0.1%**	**0.1%**	**0.2%**	**0.0%**	**0.4%**	**0.0%**	**0.2%**	**0.1%**
Food processors	**0.0%**	**0.1%**	**0.1%**	**0.0%**	**0.1%**	**0.0%**	**0.0%**	**0.1%**	**0.0%**	**0.1%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

ANNEX D. Census: people having agriculture, hunting or forestry as their main livelihood source



Spatial analysis based on socio-economic data available from Population Census 1998 and 2008 (see Footnote 12).
Bolded figures indicate the total amount of people in the sector in 2008, while the figures in parentheses show the change from year 1998.

ANNEX E. Census: people having fishing as their main livelihood source



Spatial analysis based on socio-economic data available from Population Census 1998 and 2008 (see Footnote 12).
Bolded figures indicate the total amount of people in the sector in 2008, while the figures in parentheses show the change from year 1998.

ANNEX F. Census: selected indicators grouped according to gender

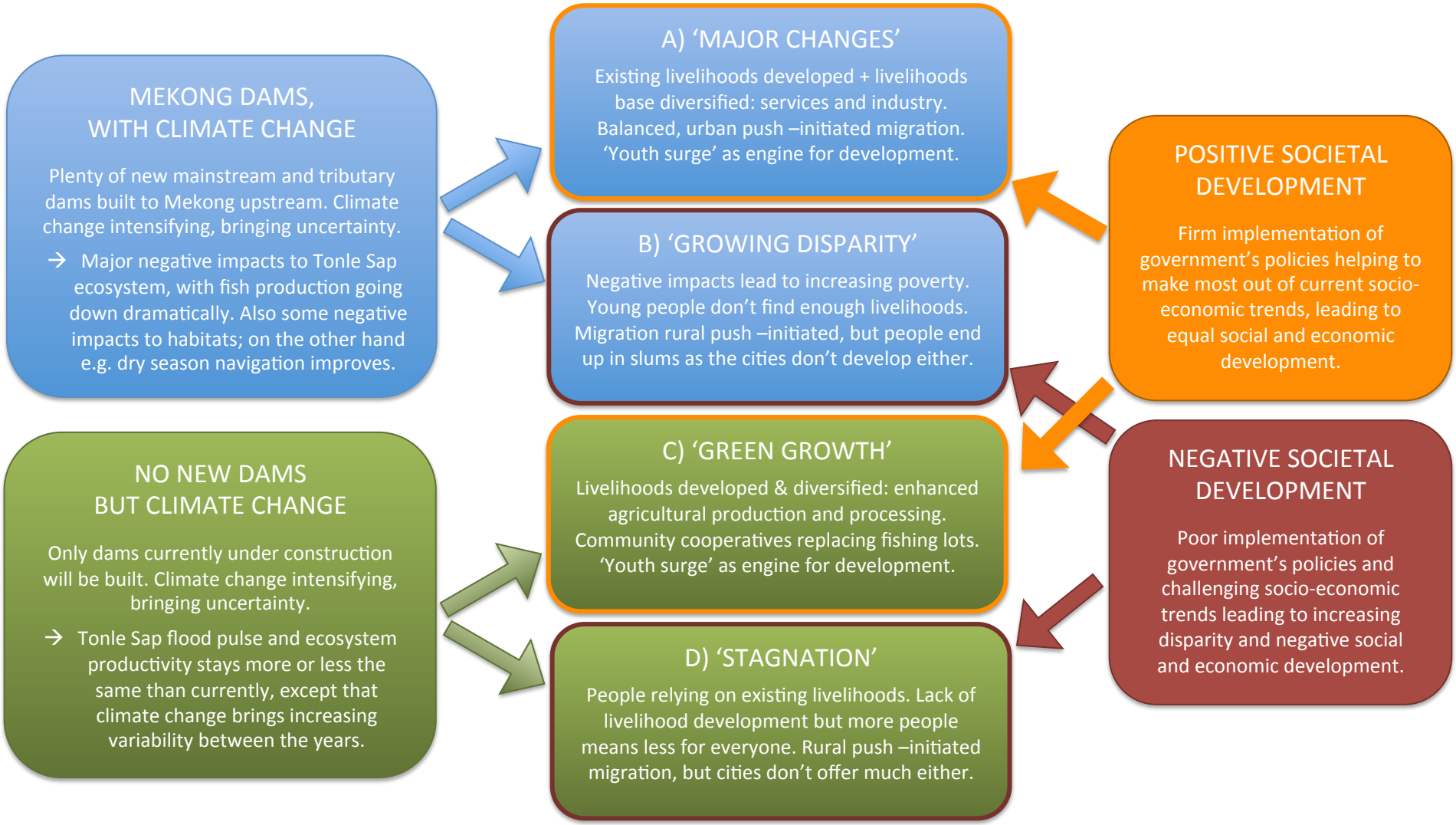
The three tables in the following three pages provide information on selected socio-economic and livelihood indicator according to gender. The information is available separately for all six provinces and their specific sub-zones as well as together for three different zones. Data from Population Census 1998 and 2008.

	Banteay Meanchey								Battambang							
	Zone 1		Zone 2		Zone 3		Province TOTAL		Zone 1		Zone 2		Zone 3		Province TOTAL	
	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008
Males	1 069	1 123	65 069	68 366	39 463	38 881	105 601	108 370	7 317	7 416	111 090	116 259	86 201	90 317	204 608	213 992
Females	1 144	1 200	69 059	71 735	41 498	40 447	111 701	113 382	7 241	7 265	120 488	122 898	92 882	95 838	220 611	226 001
Male adult literacy rate	83%	87%	83%	88%	91%	94%	86%	90%	56%	64%	83%	86%	89%	92%	84%	88%
Female adult literacy rate	60%	70%	61%	73%	71%	83%	65%	76%	39%	53%	62%	74%	70%	80%	65%	76%
Male 10-19 literacy rate	80%	92%	82%	94%	91%	96%	85%	95%	41%	62%	75%	91%	86%	96%	79%	92%
Female 10-19 literacy rate	68%	91%	77%	95%	88%	96%	81%	95%	38%	68%	73%	93%	84%	96%	77%	93%
Agriculture: Males	412	562	22 727	28 494	5 645	6 323	28 784	35 379	274	94	32 611	44 502	10 158	12 336	43 043	56 932
Agriculture: Females	428	628	23 209	30 300	5 278	6 344	28 915	37 272	138	51	33 553	45 691	9 243	11 844	42 934	57 586
Fishing: Males	1	4	225	297	145	140	371	441	2 263	3 163	1 041	1 175	339	377	3 643	4 715
Fishing: Females	1	1	59	77	73	73	133	151	931	2 090	386	614	113	153	1 430	2 857
Primary sectors: Males	413	566	22 952	28 791	5 790	6 463	29 155	35 820	2 537	3 257	33 652	45 677	10 497	12 713	46 686	61 647
Primary sectors: Females	429	629	23268	30377	5351	6417	29048	37423	1069	2141	33939	46305	9356	11997	44364	60443
Secondary sectors: Males	0	0	846	2416	1642	3483	2488	5899	30	45	2191	4451	4548	7856	6769	12352
Secondary sectors: Females	0	2	862	1837	662	2026	1524	3865	12	20	1188	2572	1801	3920	3001	6512
Tertiary sectors: Males	13	16	3553	4854	8213	10436	11779	15306	426	349	7702	9556	17757	22464	25885	32369
Tertiary sectors: Females	2	9	2629	3512	6113	9452	8744	12973	255	325	7546	9049	15311	20320	23112	29694

	Kampong Chhnang								Kampong Thom							
	Zone 1		Zone 2		Zone 3		Province TOTAL		Zone 1		Zone 2		Zone 3		Province TOTAL	
	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008
Males	10 322	10 799	31 921	37 363	19 131	19 491	61 374	67 653	4 309	4 614	53 845	65 021	25 013	26 148	83 167	95 783
Females	10 705	10 835	37 051	42 431	20 598	20 636	68 354	73 902	4 240	4 344	60 092	68 494	26 628	27 867	90 960	100 705
Male adult literacy rate	64%	60%	84%	88%	83%	84%	80%	83%	62%	56%	71%	78%	88%	88%	76%	80%
Female adult literacy rate	43%	51%	60%	74%	64%	74%	59%	71%	42%	41%	50%	63%	73%	78%	57%	66%
Male 10-19 literacy rate	48%	60%	79%	93%	79%	88%	74%	86%	41%	54%	63%	87%	89%	95%	70%	88%
Female 10-19 literacy rate	40%	61%	74%	93%	75%	89%	69%	87%	36%	56%	59%	87%	88%	95%	67%	88%
Agriculture: Males	2 475	2 441	11 721	15 236	1 310	1 870	15 506	19 547	330	449	17 532	28 000	5 033	6 422	22 895	34 871
Agriculture: Females	2 936	2 771	17 876	20 168	1 796	1 774	22 608	24 713	269	438	19 689	31 329	5 030	7 279	24 988	39 046
Fishing: Males	1 983	2 858	370	536	1 388	1 437	3 741	4 831	1 700	2 282	170	555	150	115	2 020	2 952
Fishing: Females	1 725	2 303	354	420	826	944	2 905	3 667	1 047	1 653	72	279	63	62	1 182	1 994
Primary sectors: Males	4 458	5 299	12 091	15 772	2 698	3 307	19 247	24 378	2 030	2 731	17 702	28 555	5 183	6 537	24 915	37 823
Primary sectors: Females	4661	5074	18230	20588	2622	2718	25513	28380	1316	2091	19761	31608	5093	7341	26170	41040
Secondary sectors: Males	75	124	295	877	770	1338	1140	2339	7	9	545	1285	669	1120	1221	2414
Secondary sectors: Females	41	71	172	1063	464	1474	677	2608	9	7	278	707	346	548	633	1262
Tertiary sectors: Males	711	748	2243	2998	4562	5452	7516	9198	113	142	2316	3749	3915	5156	6344	9047
Tertiary sectors: Females	649	619	1512	2217	4600	5488	6761	8324	70	141	1850	3278	3331	4749	5251	8168

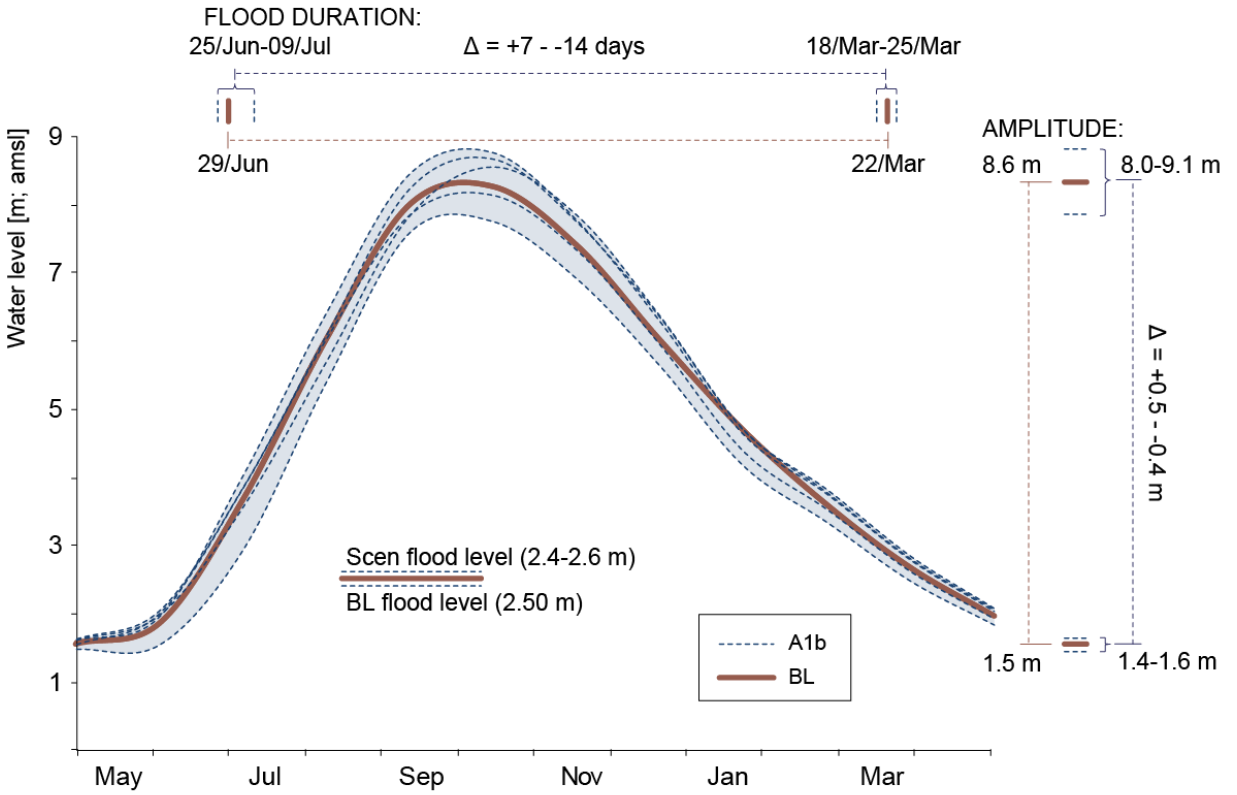
	Pursat								Siem Riep								ZONE 1 total		ZONE 2 total		ZONE 3 total		Grand Total	
	Zone 1		Zone 2		Zone 3		Province TOTAL		Zone 1		Zone 2		Zone 3		Province TOTAL									
	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008
Males	7 910	7 437	75 014	84 891	19 901	19 982	102 825	112 310	8 584	10 832	100 793	126 896	52 893	95 590	162 270	233 318	39 511	42 221	437 732	498 796	242 602	290 409	719 845	831 426
Females	7 786	7 527	83 697	92 060	22 371	22 203	113 854	121 790	9 290	11 099	109 944	132 557	56 952	96 226	176 186	239 882	40 406	42 270	480 331	530 175	260 929	303 217	781 666	875 662
Male adult literacy rate	53%	52%	84%	85%	92%	92%	83%	84%	68%	75%	73%	82%	82%	91%	76%	85%	61%	63%	79%	84%	87%	91%	81%	86%
Female adult literacy rate	36%	39%	60%	70%	73%	80%	61%	70%	53%	66%	55%	70%	64%	81%	58%	75%	44%	53%	58%	71%	69%	80%	47%	73%
Male 10-19 literacy rate	39%	56%	73%	90%	89%	94%	74%	88%	62%	79%	68%	92%	80%	94%	72%	92%	49%	65%	73%	91%	86%	94%	76%	91%
Female 10-19 literacy rate	36%	53%	67%	90%	86%	93%	69%	88%	59%	83%	65%	92%	77%	93%	68%	92%	44%	66%	69%	92%	83%	94%	72%	91%
Agriculture: Males	345	818	25 601	35 679	2 360	3 215	28 306	39 712	868	1 559	36 591	50 924	5 651	6 497	43 110	58 980	4 704	5 923	146 783	202 835	30 157	36 663	181 644	245 421
Agriculture: Females	467	938	35 430	43 772	3 535	4 332	39 432	49 042	931	1 840	43 631	59 682	6 514	6 175	51 076	67 697	5 169	6 666	173 388	230 942	31 396	37 748	209 953	275 356
Fishing: Males	2 756	2 905	330	755	35	47	3 121	3 707	2 525	3 883	720	1 157	1 060	815	4 305	5 855	11 228	15 095	2 856	4 475	3 117	2 931	17 201	22 501
Fishing: Females	1 986	2 628	187	523	24	10	2 197	3 161	1 835	3 031	127	510	537	376	2 499	3 917	7 525	11 706	1 185	2 423	1 636	1 618	10 346	15 747
Primary sectors: Males	3 101	3 723	25 931	36 434	2 395	3 262	31 427	43 419	3 393	5 442	37 311	52 081	6 711	7 312	47 415	64 835	15 932	21 018	149 639	207 310	33 274	39 594	198 845	267 922
Primary sectors: Females	2453	3566	35617	44295	3559	4342	41629	52203	2766	4871	43758	60192	7051	6551	53575	71614	12 694	18 372	174 573	233 365	33 032	39 366	220 299	291 103
Secondary sectors: Males	212	69	552	1269	780	1318	1544	2656	83	108	1131	5618	3345	9830	4559	15556	407	355	5 560	15 916	11 754	24 945	17 721	41 216
Secondary sectors: Females	91	40	358	776	361	687	810	1503	92	120	717	3004	1184	3334	1993	6458	245	260	3 575	9 959	4 818	11 989	8 638	22 208
Tertiary sectors: Males	650	394	4027	6193	4412	5204	9089	11791	368	607	4912	10384	11174	32317	16454	43308	2 281	2 256	24 753	37 734	50 033	81 029	77 067	121 019
Tertiary sectors: Females	698	401	2784	4685	4098	4684	7580	9770	601	754	4345	8621	9371	26579	14317	35954	2 275	2 249	20 666	31 362	42 824	71 272	65 765	104 883

ANNEX G. Four alternative futures and their drivers (dams + societal development)

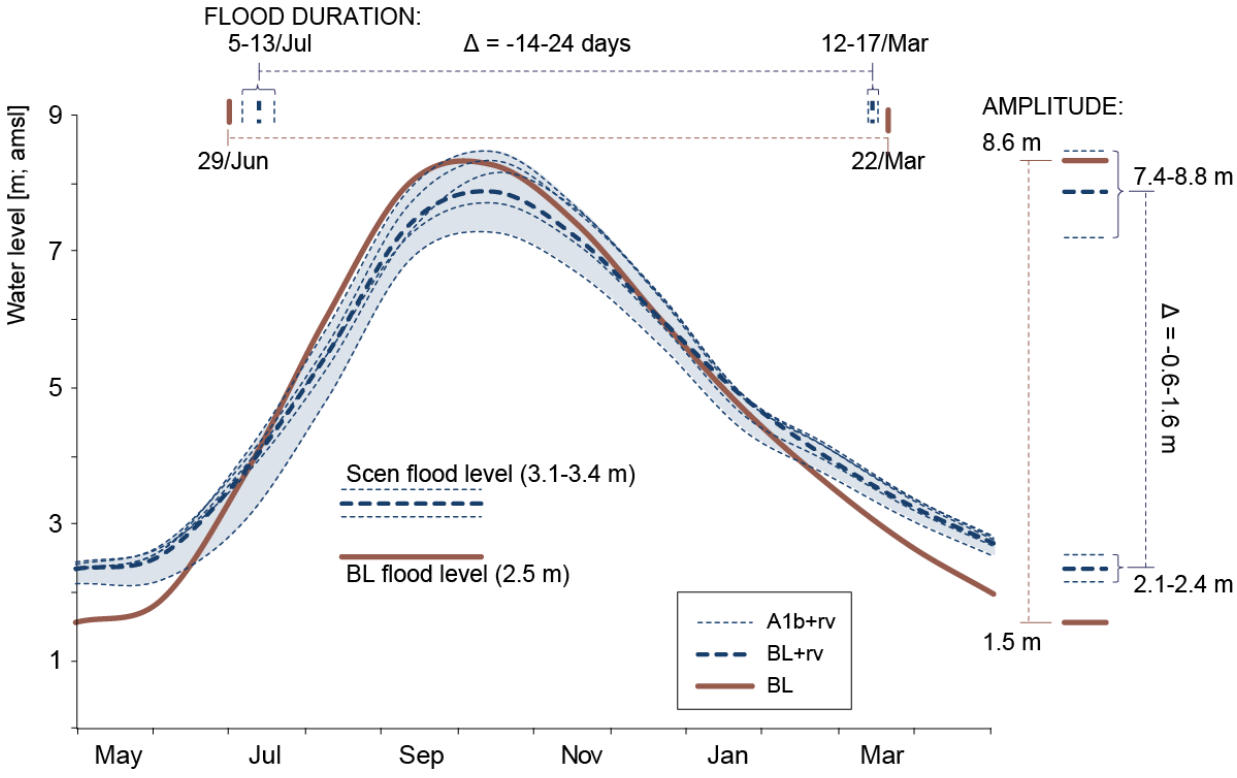


ANNEX H. Changes in flood pulse characteristics in the Tonle Sap Lake

A: Climate change (A1b)



B: Climate change (A1b) and reservoir operation (rv)



Note: The reference point for the Tonle Sap Lake is Kampong Luong.

ANNEX I. Excerpts from National Strategic Development Plan Update

Below are selected excerpts from the Royal Government of Cambodia's National Strategic Development Plan Update 2009-2013 (RCG 2010). The excerpts were together with the Rectangular Strategy (Figure 12) used as a basis when creating alternative policy responses for the four alternative futures for the Tonle Sap in 2040 (Part 3). Emphases in *blue italics* by the authors.

General objectives of the Rectangular Strategy

"The implementation of the 'Rectangular Strategy' is the further efforts to sustain the achievements that the Royal Government has hitherto realised the 'Millennium Development Goals' with the aim of improving and enhancing public institutional capacity, *promoting good governance, and modernising economic infrastructure* in order to foster economic growth, *create jobs for all citizens, ensure social equity,* and increase public sector efficiency as well as *protect natural and cultural resources, which is vital for sustainable development and poverty reduction*" (RCG 2010: ii i.e. Foreword by Prime Minister Hun Sen).

"…the Royal Government will vigorously work towards achieving a greater *'net real transfer' of development resources to the targeted vulnerable and poor* beneficiaries in our rural communities" (RGC 2010: iii i.e. Foreword by Prime Minister Hun Sen).

"The over-riding goal of the Royal Government of Cambodia is to firmly and steadily build a Cambodian society which enjoys peace, political stability, security and social order, and *sustainable and equitable development*, with strict adherence to the principles of liberal multi-party democracy, respect for human rights and dignity; and a society in which social fabric will be strengthened to ensure that the Cambodian people are *well-educated, culturally advanced, engaged in dignified livelihood and living in harmony both within family and society*" (RGC 2010: 99).

"For the Royal Government the most formidable development challenge is the reduction of poverty and *improving the livelihoods and quality of life of the rapidly growing population*. The Royal Government consider poverty to be a waste of a valuable economic resource which is not only morally unacceptable but can also result in *social polarisation and instability*" (RGC 2010: 99).

"Increasing revenue collection through *broadening the tax base and strengthening administrative compliance"*. RCG 2010: 87)

Agricultural development (incl. fisheries and forestry)

"Cambodia's economic growth is narrowly based in which agriculture sector plays an important role. It is the *main source of employment and the core of the rural economy*. Enhancement of the agriculture sector is essential: (i) to enlarge the base of, and help sustain, economic growth; and (ii) to accelerate poverty reduction. To this end, the Royal Government's policies main goal is to *promote agriculture productivity and diversification as well as land, fisheries and forestry reforms* by addressing in package issues of agriculture technology, rural infrastructure such as roads, irrigation system and electricity and credits, markets and processing-technology, especially for exports. This requires *institutional mechanisms and highly effective coordination* for sector-wide progress and qualitative changes" (RGC 2010: 121).

"The Royal Government … will continue to place priority on increasing *agricultural productivity and diversification as well as promoting agro-industries*. The Royal Government will continue to pay further attention to increased production by *shifting from extension of cultivated area to intensive farming on the existing land*. This is to increase production, employment, and rural income, and ensure food security as well

as to *increase export* of agricultural products, especially finished goods, in particular rice. This will be achieved through an integrated approach including increased proper use of improved agricultural inputs, agricultural extension, research and development, construction and maintenance of the rural infrastructure, especially irrigation network, expansion of rural credit and microfinance, agricultural market development, organisation of farmer communities and better management of agricultural land" (RGC 2010: 121).

"Fish, a natural renewable resource, is very crucial to the livelihoods of Cambodian people in terms of food, income, and safety net. … The objectives of the Royal Government are to maintain sustainability and to ensure regeneration of natural resources including *preservation of fish resources in order to contribute to economic development, as well as to ensure the livelihoods of fishing communities*. … In order to ensure that the price of the fish reflects true economic value, the Royal Government will establish an *effective fish market mechanism* as fish is either income or expense for the poor. This market mechanism will include making the bidding process for the fishing lots more transparent, and will increase efficiency in the management of fishing lots while increasing the state revenue[21] (RGC 2010: 129)"

"The Royal Government's forestry policy is to ensure *sustainable forestry management* and the use of forests to improve the livelihoods of people living in rural areas and to contribute to economic growth. Besides banning logging for the present, the Royal Government has established *protected and biodiversity conservation forest areas,* undertaken reforestation, formed forestry communities, taken up proper boundary demarcation and strict measures to prevent, reduce and eradicate illegal encroachments and occupation of forest land by private individuals" (RGC 2010: 131).

Water resources management

The recent activities of the Ministry of Water Resources and Meteorology (MWRAM) have included to "Conduct *studies on river basins round Tonle Sap River* and other major rivers … to conserve and develop water resources sector in an effective and sustainable manner; as well as *prepare a master plan on water resources management* in the Kingdom of Cambodia" (RGC 2010: 49).

"The Royal Government of the Fourth Legislature will continue to accord priority to the rehabilitation, construction, maintenance and *efficient management of irrigation infrastructure*, water reservoirs, canals, pipes, drainages, flood and sea protection levees, and water pumping stations to increase irrigated areas and boost agricultural production. The Royal Government will pay more attention to the *rights of access of people to clean water supply to ensure food safety and better livelihoods* in accordance with the Cambodia Millennium Development Goals (CMDGs) and will also preserve the ecosystem of unpolluted water and clean environment. As part of the vision for the future in water management in the Mekong basin, the Royal Government will continue to take measures to *rationalise water use in all water bodies, including rivers, lakes and the Tonle Sap Lake*" (RGC 2010: 143).

"The Royal Government will enhance efficient management of the irrigation system by strengthening the institutional capacity of concerned ministries and agencies. It will further increase *people's participation in the decentralised management and use of the irrigation systems* in order to address water issues for cultivation, facilitation of navigation and promotion of aquaculture, and will strengthen the capacity of water user communities. Along with use of resources from development partners and its own resources, the Royal Government will *encourage private sector participation in the development and the management of irrigation systems* and clean water supply" (RGC 2010: 143).

[21] It should be noted that the Cambodia's fishing lot system was abolished by Prime Minister Hun Sen in April 2012, leaving only selected fishing lots (e.g. bagnets in Tonle Sap River) as operational and releasing all other fishing lot areas to the public use (see e.g. MRC 2012).

Environmental conservation & climate change

"To implement RGC's priority policies for the Fourth Legislature, the Ministry of Environment (MOE) will:

- Ensure *sustainable use of natural resources* and implement measures that require the *Environmental Impact Assessments of the proposed development projects* before their implementation are licensed.
- Ensure that *ecology system and water environment will not be polluted*.
- Prevent and *reduce environmental pollution*.
- Strengthen NPA management of in order to eliminate anarchy in those areas, *eliminate illegal exploitation of natural resources*, and control land clearing for use and illegal cutting down of the forests.
- Ensuring the compliance with and enforcement of the Law on Environment.
- Seek for financial resources and support for *dealing with climate change issues*, both the adaptation measures and reduction measures for green-house gas emission." (RCG 2010: 132)

Energy sector development

"The Royal Government will attach priority to *increase electricity supply capacity* and reduce tariff to an appropriate level while strengthening institutional mechanism and management capability. To this end, the Royal Government will encourage the *construction of low cost electricity generating plants by using local energy sources such as hydro power, natural gas, and coal.* In addition, the Royal Government will explore possibilities of developing high-tech power plants including nuclear and non-traditional energy, and will pursue the import of electricity from neighbouring countries. The *diversification of energy resources* and the creation of the reserve generating capacity in the system are key to ensure energy security in Cambodia" (RGC 2010: 148-149).

"In order to reduce poverty and ensure harmony in the lives of people in the rural areas, the Royal Government will continue to attach *priority to accelerate rural electrification, including the use of renewable energy.* … The Royal Government considers *oil and gas resources as a unique potential to ensure energy security* and as valuable resources for long term economic development of Cambodia. In this sense, the Royal Government will develop policy, legal and regulatory framework for the sector in order to ensure efficient management and resources utilisation for economic development and improvement in livelihoods of the Cambodian people. … The Royal Government encourages the *use of efficient energy with minimal impact on the environment*" (RGC 2010: 149).

Private sector development and employment

"As an important part of the policy for diversifying the economic base, the Royal Government will promote a favourable climate for *developing the agro-processing industry*, and assembling industry including electronic and machinery assembly. In addition, the Royal Government will continue enhancing necessary legal framework, especially creating the law for the efficient operations of Special Economic Zones. … The Royal Government will continue promoting the *public and private sector partnership for investment* especially for physical infrastructure projects" (RGC 2010: 154)

"Creating jobs and ensuring improved working conditions are the RGC's continuing long-term goals aiming at enhancing the living standards of the population and ultimately alleviating poverty and accelerating economic growth. The creation of new job opportunities, however, is dependent on the level of *investments by the private sector in the formal and informal sectors in both urban and rural areas.* Ensuring that the skills of the new entrants match with the requirements of the new jobs is a challenge that will require more efforts

focused on *expanding technical and vocational education.* To achieve the generation of more employment and to *improve agriculture sector productivity and diversification* will depend on the availability of skilled labour and rural credits that can be developed through technical education and vocational training and micro-finance development" (RCG 2010: 57-58).

"The Royal Government continues to promote the *'one village-one product' movement* by encouraging inventions, entrepreneurship, and self-confidence in rural areas. This movement provides a comprehensive network *linking production to the market*, helps maintain regional identity, and encourages new initiatives for product diversification" (RGC 2010: 160).

Human resources development (incl. education, health, population policy)

"The Royal Government remains committed to developing and implementing a comprehensive and sustainable *social safety net system aimed at protecting the livelihoods of the poor and most vulnerable segments of the population*" (RGC 2010: 163).

"The Royal Government will continue to implement the Education Strategic Plan, putting emphasis on ensuring that *all Cambodian children and youth have equal opportunity for access to basic education*, both formal and informal, without discrimination … The Royal Government will pay attention to *improve the quality of education*" (RGC 2010: 167).

"The Royal Government will continue to *expand informal education* through literacy and vocational programmes, establishment of community learning centres and implementation of equity programmes. The government will increase budget allocation for education and mobilise more financing to enable clear and strategic steps to improve the overall quality of education. In *higher education*, as noted in the previous NSDP, there is an ever-increasing need for tertiary graduates who will become the scientists, workers and citizens of the future, people who can think critically and make evidence-based decisions which will impact Cambodia's short and long-term future" (RGC 2010: 168).

"In the Fourth Legislature, the Royal Government will continue to implement the Health Strategic Plan to reduce maternal mortality rate and infant mortality rate, and *improve other health indicators by enhancing and expanding health* services, especially reproductive, maternal, and infant and children health services" (RGC 2010: 173).

"The Royal Government continues to *increase women's role and capacity in decision-making* at all levels of governance and pays attention to skills training for women at all levels. The Royal Government will strive to increase the ratio of women at all government levels, by providing *employment opportunities for women*, using advocacy at the village and commune levels throughout the country, and by protecting the rights of working women" (RGC 2010: 178).

"In the Fourth Legislature, the Royal Government will continue its efforts to *integrate the population policy into socio-economic policy, plans and programmes at all levels.* The Royal Government continues to introduce necessary measures to *enhance the quality of life of people through developments in education, health, gender equity, and rural development as priority*. With 54.1 percent of Cambodian population aged below 24 years of age, it is *important that we adopt measures to turn youth to be an important driving force for development of all sectors.* The Royal Government will strengthen urban and agglomeration management to make cities clean without litter, with full sanitary facilities, with fresh air, green park and gymnasium complexes; and organise cultural entertainment publications to support enhancement of quality of physical and moral human health" (RGC 2010: 183).

ANNEX J. Local water development in the Tonle Sap Basin

As part of our study, we also carried out an analysis of the local irrigation and hydropower development in the catchment and the floodplain of the Tonle Sap (Paradis et al. 2012).

The information on the irrigation development was mainly extracted from the CNMC's Tonle Sap Sub-area report (Mak et al. 2012), and the data was complemented by the analysis of the irrigation reservoirs done with the help of Google Earth. The information on hydropower development was compiled from various sources, including GMS Program (2009), MIME (2009), MRC (2009c), EDC (2011), Mak et al. (2012) and ODC (2012). Map below summarises the spatial data on the dry-season irrigation structure and hydropower development in the Tonle Sap catchment.

For more information, please see Paradis et al. (2012).