Using Scenarios for Information Integration and Science-Policy Facilitation: Case from the Tonle Sap Lake, Cambodia

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The interconnections between water, food, energy and climate in Cambodia's unique Tonle Sap area were looked at in a two-year interdisciplinary research project. Several research methods were applied in the project, ranging from hydrological modelling to socio-economic database analysis and household surveys. These more traditional research methods were then complemented with the application of scenario approaches that made use of scenario narratives, scenario workshops and, ultimately, alternative scenario formulation. As a result, the main research results were synthesised – and, importantly, communicated and discussed – through four alternative scenarios created for the Tonle Sap in 2040, indicating radically different but nevertheless plausible futures for the area. While the hydrological and livelihood analyses created the basis for the understanding of key drivers in the area, the scenario process facilitated integration of diverse, discipline-specific information. In addition, the possibility to discuss alternative storylines allowed better consideration of the uncertainty and complexity included into the analyses.

Introduction and Background

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 (e.g. Keskinen et al. 2013; MRCS/WUP-FIN 2007; MRC 2010; Mak et al. 2012).

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, tourism, construction, and industrial activities. At the same time, the livelihood structure of the Tonle Sap area is diversifying, with increasing amount of people transferring from traditional, agriculture-based livelihoods to more modern sources of income, and the provincial capitals – Siem Reap in particular – attracting migrants from the rural areas (Keskinen et al. 2013).

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 and the lake system is considered to be the most vulnerable for the planned large-scale hydropower development in the Mekong Basin. (e.g. Lamberts & Koponen 2008; Kummu & Sarkkula 2008; Keskinen et al. 2013; Arias et al. 2014; Kummu et al. 2014)

This article presents the main methods and findings of the so-called 'Exploring Tonle Sap Futures' research project (http://www.wdrg.fi/research/exploring-tonle-sap-futures), building on the Final Report of the project (Keskinen et al. 2013). The project was part of the regional 'Exploring Mekong Region Futures' programme (http://www.csiro.au/science/MekongFutures). It sought to increase the understanding of the future development of the Tonle Sap area through in-depth analysis of hydrology and livelihoods. These two research components were then supplemented by scenario formulation process. This article described the main methods and key findings of this research project, with the discussion focusing on the usefulness of the scenario approach in synthesising and communicating the findings from the more traditional research.

Material and Methods

A central part of the Exploring Tonle Sap Futures project were two research components focusing on water as well as on demography and livelihoods (Keskinen et al. 2011, 2013). The research component on water ('Hydrological analysis') analysed the possible impacts of regional changes – focusing on Mekong hydropower development and climate change – to the Tonle Sap system and its exceptional flood pulse (Lauri et al. 2012). The analysis was carried out with the help of two mathematical models. A hydrological model called VMod was established for the whole Mekong basin, and it was used to simulate the cumulative impacts of development and climate change on the Mekong flow regime. The VMod model was then linked to a more detailed EIA 3D floodplain model that simulated the impacts of basin-wide cumulative changes on the Tonle Sap flood pulse. The regional climate change scenarios for the hydrological model were obtained by downscaling five different global climate change models (GCMs) for the Mekong Basin, while the MRC hydropower database was used to estimate the future development in the large-scale hydropower construction in the Mekong Basin (Keskinen et al. 2011; Lauri et al 2012).

The research component on demography and livelihoods analysed then current demographic, social and economic setting and trends in the Tonle Sap area. The livelihood analysis built on extensive 'spatio-statistical' analysis[42] of the key socio-economic databases (Population Census 1998 and 2008), and it was complemented by the CSIRO Tonle Sap Household Survey that included 1000 household interviews in 50 villages in the area (Ward & Poutsma 2013; Salmivaara et al. submitted). Due to Cambodia's tumultuous history, the Population Censuses of 1998 and 2008 are the first ones since 1960s and they thus provide a major opportunity to look at the demographic and socio-economic trends at the village level. Yet, there has to our knowledge been very few analyses done on such trends anywhere in Cambodia, and none in the specific context of the Tonle Sap.

The two research components were then supported by a scenario process that included three phases. The process was initiated by the creation of alternative of scenario narratives for the Tonle Sap, produced during the first two stakeholder workshops (Foran et al. 2011). These scenario narratives helped then to focus the actual

[42] The term 'spatio-statistical approach' indicates that the available quantitative data is analysed with spatial approach, and that the robustness of the approach has been tested statistically.

research that was discussed in the following workshops. The workshops were organised by the governmental 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. Finally, the research findings were then put synthesised through the creation of four alternative scenarios for the Tonle Sap in 2040 (Keskinen et al. 2013).

Results

This section presents the selected key findings from the hydrological and demographic & livelihood analysis: for more detailed results, please see Keskinen et al. (2013), Lauri et al. (2012) and Salmivaara et al. (Submitted).

Hydrological analysis[43]

The impact from the Mekong hydropower development and climate change was analysed in our study 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.

The results indicate clearly that the flood pulse of the Tonle Sap is likely to change in the future, with the planned hydropower dam development in the Mekong River Basin causing dramatic changes on the flood dynamics. The hydropower operation will flatten the hydrograph by causing higher dry season water levels and lower flood peaks. Climate change, on the other hand, 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, in the Tonle Sap system. Yet, our analysis indicates that the exact impact of climate change remains unclear, mainly due to differences in the different GCMs applied to the Mekong Region and whole monsoon Asia (e.g. Ashfaq et al. 2009). Even the direction of the change caused by climate change differs depending on the emission scenario and GCMs used. 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).

Within the timeframe used in our study (i.e. by year 2042), climate change alone does not have a considerable impact on the dry season water level in the lake. In addition, even the direction of climate change impact on the Tonle Sap flood peak is unclear. 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. This would mean that the permanent lake area would increase 18–31%, submerging important habitats of, for example, flooded forest (Figure 1). For the flood season water levels the cumulative impacts are significant, with modelling estimates indicating lower flood peaks, although with large uncertainty due to the differences in GCMs used in the study. The flood-

[43] This chapter is based on the following two main sources: Lauri et al. 2012 & Keskinen et al. 2013.

plain 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.

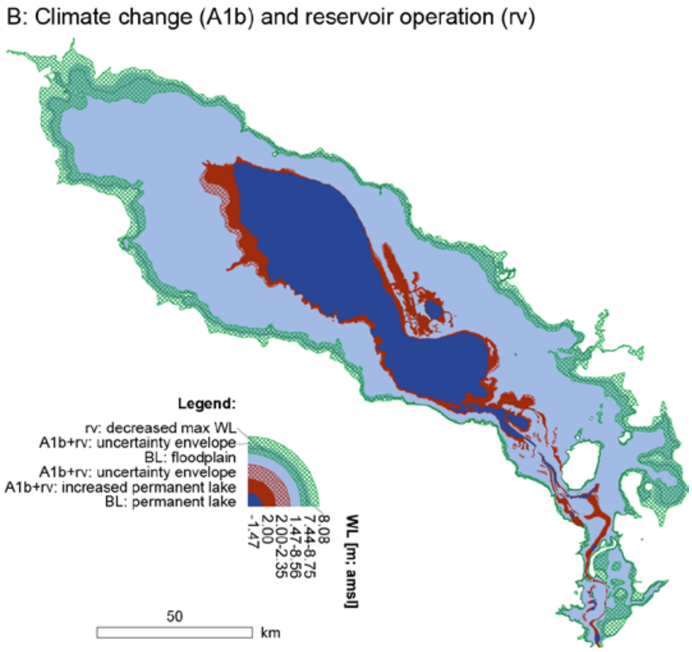

Figure 1. Map of the estimated future changes (2032-2042) caused by the cumulative impacts of climate change (A1b) and reservoir operation (rv) in the permanent lake and flooded areas compared to the baseline (BL; 1982–1992). Source: Keskinen et al. 2013.

Demographic and livelihood analysis[44]

The Tonle Sap area as defined in this research[45] includes 1555 villages, and the analysis of this extensive dataset therefore requires some classification. Based on the topographic zoning and the level of urbanisation and supported by statistical analysis, the Tonle Sap area was divided into three zones: Zone 1 (Lower Floodplain), Zone 2 (Upper Floodplain), and Zone 3 (Urban) that were further divided into 18 sub-zones based on the administrative boundaries of the six Tonle Sap provinces. The created three zones have very different relationships to the lake and its annual flood pulse, as the flood pulse impacts greatly on the floodplain functions and vegetation (Arias et al. 2013). It is also critical to note that the three zones differ greatly in terms of both population and area, with Zone 2 clearly having the biggest population and Zone 1 being the largest area-wise.

According to the data received from the Population Census 2008, there were 1'707'000 people living in the Tonle Sap. A great majority (1244) of the Tonle Sap villages are 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 throughout the Tonle Sap, searching for meaningful work opportunities

[44] This chapter is based on the following two main sources: Salmivaara et al. Submitted & Keskinen et al. 2013.

[45] The Tonle Sap area was in this research defined to be the area between National Roads 5 and 6, with a 3-kilometer buffer beyond the roads .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 (Keskinen et al. 2013).

and changing dependency ratio (Figure 2). 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; 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.

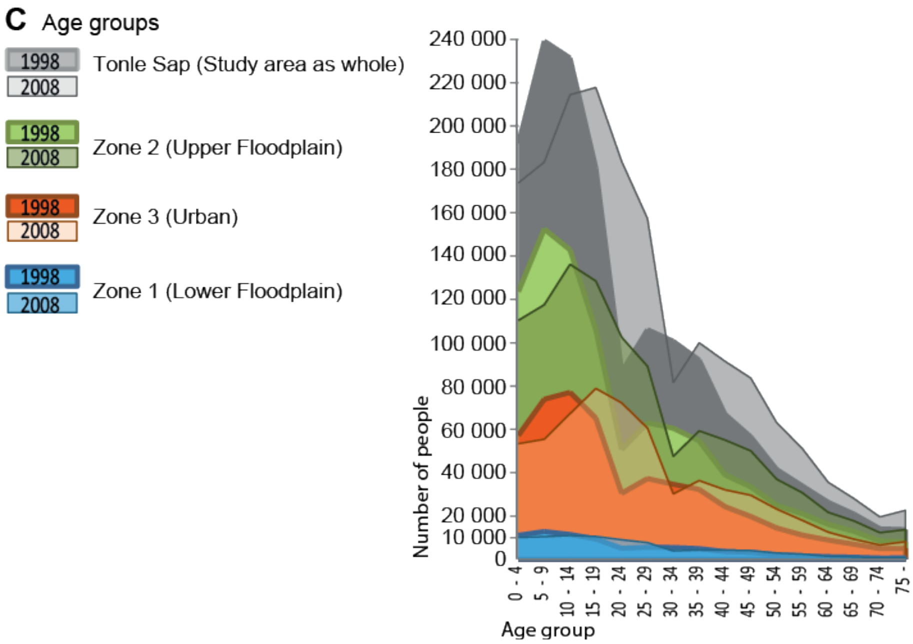

Figure 2. Age profiles according to five-year age groups for the entire Tonle Sap area as well as for each of the three zones separately, showing very clearly the so-called youth surge. Source: Salmivaara et al. Submitted.

Overall, the Tonle Sap area is changing both socially and economically, but the pace varies notably across the area. 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%). The CSIRO Tonle Sap Household Survey (Ward & Poutsma 2013) 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.

While the proportion of workforce engaged in the 'Agricultural, hunting and forestry' sector (great majority of which is agriculture) decreased from 66% in 1998 to 61% in 2008 the amount of workforce in the sector increased remarkably, i.e. by 130,000 people, due to population growth. This naturally indicates an additional pressure on agricultural land and related resources. Similar finding was evident in fishing sector, where the proportion of people involved in the sector has decreased slightly (from 4.7% in 1998 to 4.5% in 2008), but due to population growth the absolute number of people having fishing as the main economic activity increased by 10,700 between 1998 and 2008.

While the agriculture, trade and fishing keep on dominating the livelihood portfolio in the Tonle Sap, there are signs for increasing livelihood diversification as well. The most rapidly growing livelihood sector in the Tonle Sap between 1998 and 2008 was construction that increased from 1% in 1998 to 4% in 2008. Other increasing (although still minor) livelihood sectors include manufacturing, hotels and restaurants, other service activities, and real estate, renting and business activities.

Alternative scenarios created for the Tonle Sap in 2040[46]

The findings presented in the two chapters above provide differing views for water- and livelihood-related future changes in the Tonle Sap. The findings 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 the future.

For these reasons, we felt that it doesn't make sense to generate just one possible view – or best guess – about the ways the hydrology, demographic and livelihoods are likely to develop in the future. Instead, we decided synthesise our research by creating four alternative scenarios (or alternative futures) for the Tonle Sap in 2040. The four alternative scenarios build on the possible changes and trends that water and livelihoods will bring to the area, but they were also influenced by the future-oriented scenario narratives that were created during the first two stakeholder workshops (Foran et al. 2011. The key research findings presented above influenced therefore greatly to the way the four alternative scenarios were formed: they essentially formed the frames within which we allowed us to create the alternative futures.

In this way our alternative scenarios – 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 generally include major surprises or irregularities. There are also other, more innovative and less rigid ways to create scenarios: see e.g. Schwartz (1996), van Notten (2006), Foran et al. (2011), Heikinheimo (2011), Smajgl et al. (2011) and Zhu et al (2011). Despite this, we still feel that the following scenario description by IPCC (2012) 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."*

The starting point for the scenario formulation for the Tonle Sap 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: 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 (RCG 2001, 2010).

Together, two 'water paths' and two 'societal development paths' create then four alternative scenarios for the Tonle Sap by 2040: A) Major changes, B) Growing disparity, C) Green growth, and D) Stagnation (Figure 3). In

[46] This chapter is based on Keskinen et al. 2013.

the Final Report of the research project (Keskinen et al. 2013), each of this alternative scenarios were then described in more detailed level, including the policy implications included in each of them. The Final Report also includes description of three 'surprise factors' – or wild cards – that could influence remarkably the development in the area. Such surprise factors were drawn from the discussions emerging during the stakeholder workshops and included intensive oil and gas extraction in the Tonle Sap; Tonle Sap algae for renewable energy; and Tonle Sap as Southeast Asia's prime ecotourism destination (Keskinen et al. 2013).

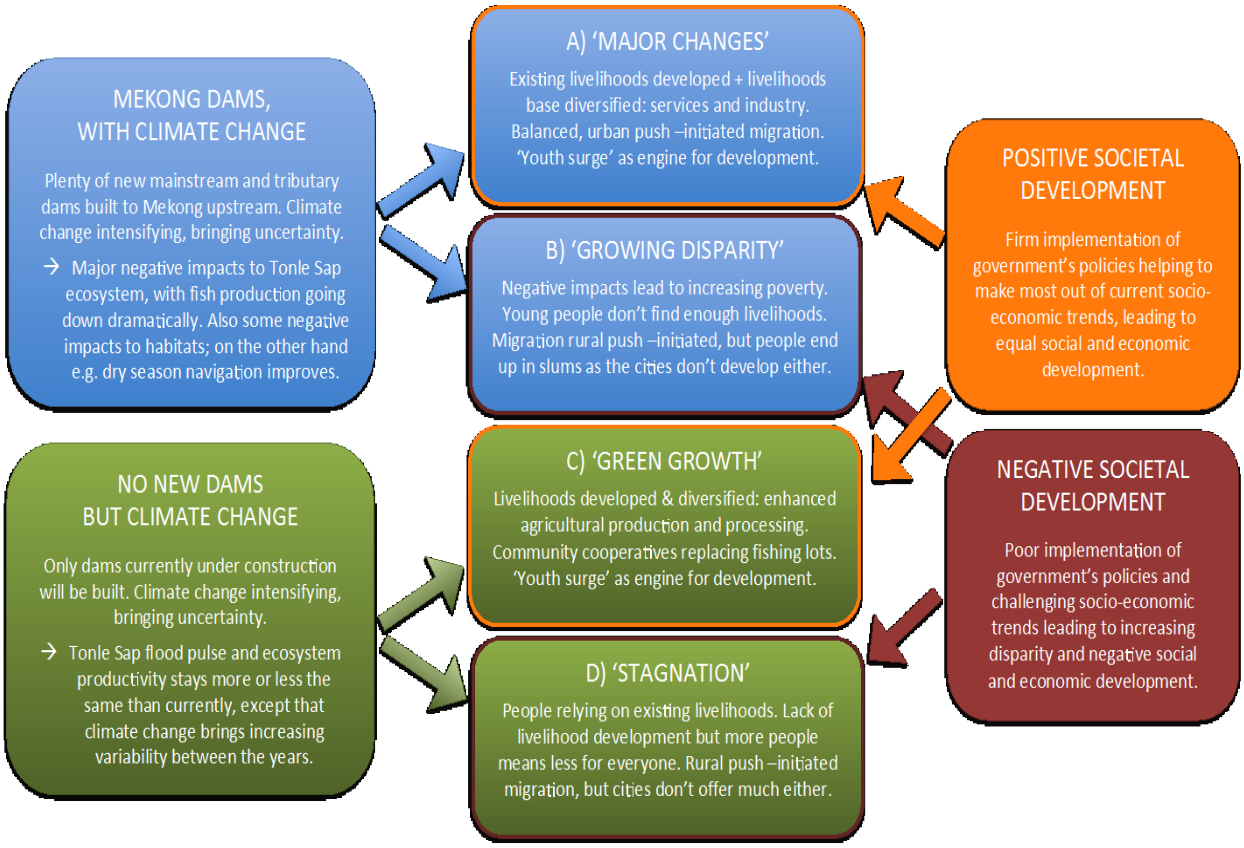

Figure 3.Visualisation and brief description of the four alternative scenarios created for the Tonle Sap in 2040: for explanations, see text. Source: Keskinen et al. 2013.

The scenario process also means that each alternative scenario is similar to two other alternative futures: they either share same 'water path' or have similar 'societal development path'. In this way our alternative scenarios differ from conventional scenarios that seek to be more clearly different from each other. 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 demographic and socio-economic – 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).

Discussion

Using scenarios for information integration and science-policy facilitation

This article first presented the overall context of the Tonle Sap are in Cambodia, and then proceeded to present the key research findings from our recent research project focusing on hydrological as well as demographic and livelihood analyses. Finally, we introduced the four alternative scenarios that were created for the Tonle Sap, with two specific aims: 1) to integrate the diverse information related to water resources, the environment and people, and 2) facilitating science-policy interaction by providing a novel platform for discussion about the Tonle Sap's future.

Overall, the four alternative scenarios created for the Tonle Sap in 2040 provide a perspective on the possible future paths that the Tonle Sap area may experience, building on the hydrological as well as demographic and livelihood analyses carried out as part of the research project. While the basic setting depends on external driving forces such as Mekong hydropower development, the scenarios also indicate that the future development of the Tonle Sap depends very much on the way the area's socio-economic setting and livelihoods are evolving. In this, the policies and governance structure applied by the Cambodia's central government and provincial and district authorities assume a primary role.

Our experience indicates that scenarios facilitate integration of diverse, discipline-specific information, particularly through creation of comprehensive future storylines/scenarios that combine information from different sources and analyses. Possibility to discuss several alternative storylines allows also better consideration of the uncertainty and complexity related to water and its management. We also see that scenarios provide a powerful way to take the views of different stakeholders into account when planning and implementing research as well as when presenting research findings. This way the scenarios also helped to strengthen science-policy-practice linkage. Scenarios also allowed us to look at and discuss decision-making processes and policies, which is in many settings not that easily done for example for political reasons.

At the same time our experience reminds us that scenarios need to be used with caution, as due to the comprehensiveness and complexity included in the scenario formulation, they can easily become rather subjective. Scenarios are thus easily guided – intentionally or not – with certain perceptions and mental models, emphasising the need for careful facilitation. Even then, scenarios should be considered more as subjective interpretations created (and to be used) in a specific context, rather than as general conclusions from a research project.

Water-energy-food-climate nexus

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 also has a strong spatial dimension, as the decisions related to energy production are done at a 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, including for example agriculture, fishing, energy, and the environment, at both national and local levels. Consequently, it is obvious that the government's policies 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. 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.

Conclusions

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. We estimate that the possible changes in the flood pulse 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. Such a radical reduction would naturally present a major challenge for the Tonle Sap area and entire Cambodia, both in terms of livelihoods and food security.

At the same time the population in the Tonle Sap area keeps on growing. The Tonle Sap is – consistent with the rest of Cambodia – experiencing exceptionally large age groups of 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. This has – luckily – also been noted by the development strategies of the Cambodian Government (RGC 2010). The livelihood structure of the Tonle Sap area remains to be 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.

The future of the Tonle Sap area thus 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. Overall, we see that the Tonle Sap development should particularly in rural areas build on existing livelihoods, with a focus on enhancing the agricultural productivity and improving the access to the markets.

In terms of methodologies used in the project, we found the scenario process to be useful in (at least) to different ways. First of all, it helped to link the results from our different research components more firmly together, hence helping the integration of variety of information integration. Secondly, the scenarios proved to be rather powerful in visualising the results and initiating the discussion about the possible future paths. In this way, they thus facilitated science-policy-practice linkages in a way that mere scientific analyses and their syntheses may not have been able to do.

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