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The Lake with Floating Villages: Socio-economic Analysis of the Tonle Sap Lake

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ABSTRACT *Increasing complexity and multidisciplinarity of water management has resulted in the development of broader approaches such as Integrated Water Resources Management (IWRM). This paper discusses the IWRM and particularly its social and participatory dimensions based on the practical experience gained from the socio-economic analysis within a modelling project in Cambodia's Tonle Sap Lake. It is argued that water-related socio-economic analysis can significantly contribute to water modelling and impact analysis work because it helps to link modelling with the most relevant social and economic issues. This way modelling is also better able to answer to the needs of integrated water resources management.*

Water, Environment and Society

Water resources management is much more than managing water. This contradictory statement is self-evident in the Mekong Basin where water equals life for millions of people for whom water provides directly or indirectly the source of livelihood. In addition to direct economic values, the basin's water resources possess remarkable social, cultural and spiritual values. The Mekong River and its tributaries constitute an important, and controversial, energy source and transportation route for the riparian countries. The river system also supports diverse aquatic and terrestrial ecosystems. The basin's immense water resources are thus the key factor for social and economic development of its riparian countries. At the same time, economic development and the increasing population put the water resources under growing stress. Therefore, understanding the interactions and interconnections between water, environment and society is an absolute necessity for balanced and equal management of the basin.

In this sense the Mekong Basin is obviously no different from any other river basin in the world. The need for integrated management of water resources has been understood around the world for decades (Biswas, 2004). However, it has only been during recent years that this type of integrated approach has been more widely and uniformly acknowledged as the most appropriate one for water management. The main reason for this is the emergence of the concept of Integrated Water Resources Management (IWRM). According to its definition, the IWRM is a dynamic process that promotes the coordinated

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management of water, land and related resources to maximize economic and social welfare without compromising sustainability of vital ecosystems (GWP, 2000). Thus, the challenging aim of the IWRM is to find a balance between three Es, i.e. Economic efficiency, Environmental sustainability and social Equity.

Information required for the integrated management of water resources therefore includes hydrological, environmental, and economic as well as social data and information. Although collating and analysing this type of diverse and multidisciplinary information is already a huge task itself, it is not enough. In order to understand and manage the interconnections and impacts between water, environment and society, the information also needs to be linked firmly together.

Consequently, the most difficult question in the implementation of the IWRM is related to the letter 'I' in its name: How to Integrate the diverse social, economic, environmental and hydrological information in a meaningful and comprehensive way to sustain the balanced management of water resources? Successful implementation of the IWRM also largely depends on the scale of the IWRM. There have been arguments that IWRM would not be the most suitable approach on a macro-scale, and particularly not in transboundary river basins, such as the Mekong, where the differences in countries' governance structures together with national interests and political rivalries make an integrated approach far more challenging (see e.g. Biswas, 2004).

This paper addresses the Integrated Water Resources Management and its challenges by presenting a case study on water-related socio-economic analysis within the Tonle Sap Modelling Project. The paper includes two intertwined themes: one that is more practically orientated and presents the methods and results of the socio-economic analysis of the Tonle Sap Lake, and the other that is more general and looks more at the overall context of the IWRM. It must be noted that the term 'socio-economic analysis' is somewhat vague and even misleading. This is so for two reasons. First, the term tries to put together two aspects that actually are very different, namely social and economic issues. This results often in a situation where one aspect is emphasized more than the other—or at worst neither of the aspects is properly dealt with. Second, the socio-economic analysis addressed in this paper focuses mainly on livelihoods. Therefore the term 'socio-economic analysis' should in this context actually be understood as a livelihood analysis rather than as thorough analysis of social and economic issues.

The Multidisciplinary Approach of the IWRM

Integrated Water Resources Management requires a multidisciplinary approach where actors from several different disciplines and institutions cooperate in an open and constructive manner (Delli Priscoli, 2004; GWP, 2000). Multidisciplinarity can have several different levels, and different meanings and dimensions at different levels. The two levels discussed in more detail in this section are referred to as the management level and project level.

As the name implies, the management level is more general where the information derived from different disciplines, or sectors, is collated and analysed in a multi- and cross-disciplinary manner. In an ideal situation the different analyses—hydrological, socio-economic, ecological, political—necessary for integrated management are not carried out by separate projects, but by one multidisciplinary team that is able to link the different sectors together from the very beginning (Delli Priscoli, 2004). In this situation separate sector projects and programmes become basically unnecessary. However, setting up this kind of multidisciplinary team is not always possible. This might be due to limitations in available resources and information, lack of institutional capacity, or due to the large scale and complexity of the research area. All three hold true at least to a certain extent for the Tonle Sap Area.

In this kind of situation the sector analyses are usually carried out in an 'old-fashioned' way in separate projects, and the results of the different analyses are integrated after at the management level. Unfortunately, this separation makes the integration of socio-economic, ecological and hydrological information more problematic due to dissimilarities between the sectors, including differences in the methods used and the type of information gathered. To overcome this problem, the sector projects should also develop more transparent and compatible approaches and hence adjust their approach towards greater multidisciplinarity. This leads to increased understanding of other sectors and their needs and requirements, and thus enables the creation of better linkages with these sectors.

The socio-economic analysis carried out within the Tonle Sap Modelling Project presents an example of the multidisciplinary approach applied at the project level: the results of the analysis are used to focus the modelling work to create firmer connections with other dimensions of the IWRM, most importantly with society. This enables modelling to address better the multidisciplinary needs set by the IWRM. At the same time it should be noted that the socio-economic analysis is by no means comprehensive, but is intended to support and complement the modelling work. Thus the analysis does not remove the need for a more extensive socio-economic analysis that is unquestionably necessary for a comprehensive understanding of the area, and consequently, for truly integrated management of the Tonle Sap.

Cambodia and Tonle Sap

Although relatively rich in natural resources, Cambodia is one of the poorest countries in Asia. Most of country's population is still heavily dependent on common natural resources for their livelihood. More than 70% of the labour force works in the agricultural sector although agriculture's proportion of the GDP is decreasing rapidly (NIS, 2004). Cambodian society is characterized by deep-rooted inequality, which is demonstrated by poverty as well as inequality in gender status and access to education. Regional differences, particularly between urban and rural areas, increase this inequality even further (Ministry of Planning, 2002).

Several decades of internal turmoil, poor management of natural resources, and weak and corrupted governance are the main reasons for the underdevelopment of the country (World Bank, 2004). However, Cambodia is slowly developing towards a more decentralized and democratic system, and this development has already enhanced economic growth, enabled development of public services and the preparation of legal reforms, and increased the inflow of foreign investment (Ramamurthy *et al.*, 2001). These are all needed in the sustainable economic and social development of Cambodia.

The Tonle Sap Lake, also known as the Great Lake, lies in the central plains of Cambodia. The 120 km long Tonle Sap River connects the lake to the Mekong River. The lake is known for its rich biodiversity and extraordinary water regime with a huge seasonal variation in water level and volume. During the wet season the water depth in the lake rises from a mere 1 m up to 10 m (see Figure 3 in Kummu *et al.*, 2006, this issue). At the same time, the surface area of the lake more than quadruples from 2500 km^2 up to 15 000 km^2, extending the lake over vast floodplains consisting mainly of flooded forests, shrubs and rice fields (MRCS/WUP-FIN, 2003).

The variation of water volume in the lake is caused by an exceptional hydrological phenomenon determined by the Mekong River. During the southwest monsoon the water level in the Mekong River rises so fast that part of the floodwaters runs to the Tonle Sap River, causing the river to reverse its flow back towards the Tonle Sap Lake that thus loses its only outlet. The largest festival in Cambodia, *Bon Om Tok,* i.e. the water festival, is celebrated in October and November after the Tonle Sap River reverses once again and starts emptying the Tonle Sap Lake back to the Mekong River.

The extraordinary water regime of the Tonle Sap Lake and River has resulted in an exceptional and highly productive floodplain ecosystem. The Tonle Sap Lake is among the most productive freshwater ecosystems and one of the most fish-abundant lakes in the world. Flooded forests and shrubs offer excellent shelter and breeding grounds for fish. Migration of different fish species and other aquatic animals between the Tonle Sap Lake and the Mekong River is extensive and diverse. During the inflow there is mostly a passive migration of eggs, fry and fish to the Tonle Sap Lake and its floodplains. Later, large numbers of fish follow the receding floodwater back to the lake and finally back to the Mekong River, while numerous species, mainly the so-called black fish, stay in the lake and adjacent water bodies inhabiting them throughout the year (Lamberts, 2001).

The socio-economic setting of the Tonle Sap Area is diverse. This is due to various reasons, including the peculiar nature of the lake, its floods and ecosystem, the area's rapidly growing population and massive incidence of poverty as well as people's deep dependence on the lake and other natural resources. Ethnic diversity, seasonal variations of livelihood sources, unequal access to natural resources, and insufficient rights of land tenure also have impacts on the area.

Due to its extraordinary role the Tonle Sap Lake can be regarded as the 'Heart of the Mekong'; without it the Mekong River and its aquatic life would not flourish as it does today. The role of the Tonle Sap for Cambodia is even greater. It has been approximated that as many as half of the country's population benefits directly or indirectly from the lake's resources (Bonheur, 2001). Therefore, the successful management of the Tonle Sap Lake is vital for both Cambodia and the entire Mekong Basin. *Vice versa*, due to its extraordinary water regime, the future of the Tonle Sap depends not only on local development, but also on the upstream development in other Mekong Basin countries because even relatively small changes in water quantity and quality in the Mekong River can have unpredictable impacts on the lake and its resources.

The Tonle Sap Modelling Project

The socio-economic analysis of the Tonle Sap Lake was carried out as a part of the Tonle Sap Modelling Project (WUP-FIN). The main aim of the Tonle Sap Modelling Project is to create a means to understand the physical, chemical and biological processes in the Tonle Sap Lake, and to assist in the maintenance of sustainable conditions of the lake (MRCS/WUP-FIN, 2003). The results and recommendations of the project are being used to support management and decision-making at different levels, ranging from regional to national and local levels.

To fulfil this demanding task, a set of hydrological, hydrodynamic and water quality models were developed within the project (Kummu *et al*., 2006, this issue). In order to facilitate impact assessment and to better link modelling into social, economic and environmental issues, the models were complemented with environmental and socio-economic surveys and analyses. This type of broad approach was seen as essential for the full and meaningful use of the developed models, but it also brought new challenges.

Perhaps the biggest challenge was the integration of diverse socio-economic information with other information sources and datasets, in particular with ecological information and modelling results. Due to the specific nature of the Tonle Sap Area, ecology is clearly the main connecting factor between socio-economic and hydrological information (Nikula, 2005). However, achieving through understanding the area's ecology proved to be extremely challenging due to ambiguity and a sheer lack of information on ecological processes and functions (Lamberts, 2006, this issue).

Another major challenge was related to differences in type of information available. While the mathematical models are based on quantitative data, socio-economic analysis (and often also environmental analyses) are based on both quantitative and qualitative information. Since qualitative information is practically impossible to include in conventional mathematical models, quantitative data is typically preferred when linking these different elements together. However, socio-economic databases have their own problems and biases, and utilization of both quantitative and qualitative socio-economic information results in a more comprehensive and up-to-date understanding of the socio-economic situation in the area.

After considering the challenges described above, the socio-economic analysis within the WUP-FIN Project was based on both socio-economic database analysis and participatory village surveys, and was complemented with expert interviews and literature reviews. To facilitate the integration between socio-economic, ecological and hydrological information, the socio-economic analysis was carried out according to topographic zones that were defined with the help of Geographic Information System (GIS). The linking of qualitative socio-economic information with modelling results was also made easier by summarizing some of the results of the village surveys with semi-quantifying methods.

The socio-economic analysis thus consisted of two main phases: (1) actual analysis phase; and (2) integration and assessment phase. The former was carried out at the beginning of the project and it analysed the most important water-related social and economic issues in the area. This increased the overall understanding of these issues in the Tonle Sap Area, and helped to set the focus for the actual modelling work. The second phase was implemented during the latter half of the project and it aimed to integrate the model results with socio-economic information to assist impact assessment, and ultimately, to give balanced management recommendations. The latter phase was closely connected with the policy analysis carried out within the project (Varis & Keskinen, 2006, this issue).

Topographic Zoning

The idea behind topographic zoning is to arrange the available village-level socio-economic information into zones according to topographic location (i.e. elevation) of the villages to allow better connection with the lake and its floods. This type of arrangement differs considerably from normal because databases usually classify socio-economic

Table 1. Topographic and urban zoning of the Tonle Sap Area

	Topographical location	Population (1998)	Number of villages (1998)	Area (km^2)
Zone 1	0–6 m (above sea level)	84 742	88	8 531
Zone 2	6–8 m (above sea level)	56 690	82	2 407
Zone 3	8–10 m (above sea level)	283 104	313	2 292
Zone 4	10 m to National Roads	470 196	554	1 574
Zone 5	Urban areas	291 460	121	73
All zones	Between National Roads 5 & 6	1 186 192	1158	14 876

information according to administrative boundaries such as provinces and districts. However, these boundaries do not follow the water flows, which makes the integration between socio-economic analysis and water resources far more challenging.

The Tonle Sap Area is well suited to this type of classification as the area's topography rises steadily further away from the lake, and the zones thus form well-defined entities (Table 1). Quantitative socio-economic data derived from the different databases were arranged and analysed according to these zones, resulting in the creation of a new, topography-based socio-economic database. Information derived from the participatory village surveys and literature reviews was also analysed according to zones, although their extremely small sample size made this analysis indicative only. The results of the hydrodynamic and water quality models were also arranged according to topographic zones, thus enabling enhanced linking between the model results and socio-economic variables.

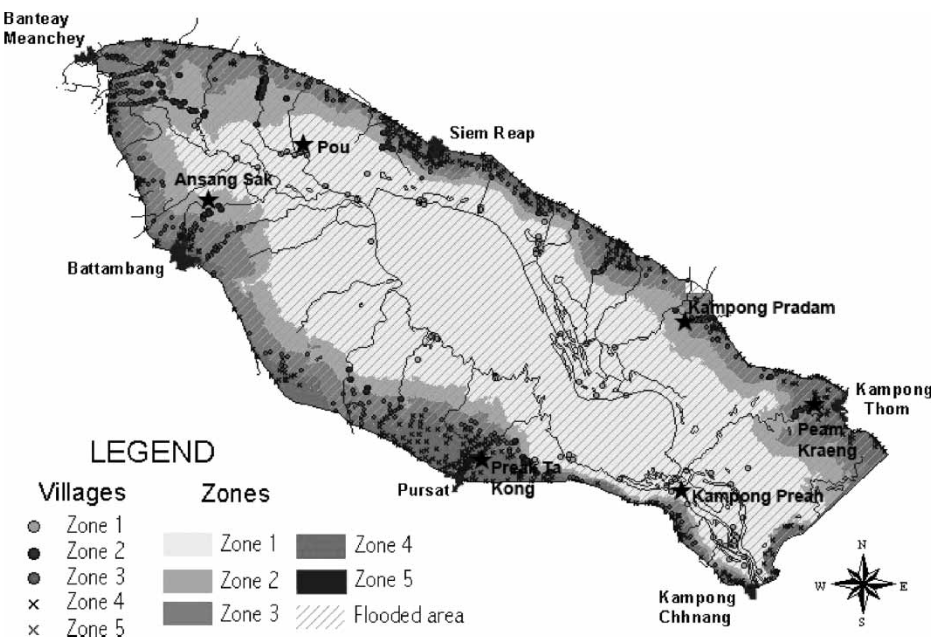

Figure 1. Tonle Sap Area with five zones and six survey villages (marked with stars). *Source:* Keskinen (2003).

Consequently, the villages of the Tonle Sap Area were divided into four topographic zones. Zones were numbered in ascending order so that Zone 1 is closest to the lake and Zone 4 furthest from the lake and closest to the National Roads 5 and 6 that were defined to be the borders of the study area (Table 1 and Figure 1). Due to the clear differences between urban and rural areas, urban areas formed their own zone based on the land use classification for the area (JICA, 1999).

Figure 1 shows a map derived from the created database for the Tonle Sap Area. As can be seen, a large majority of the population concentrates in the areas around the National Roads and provincial capitals even though most of the area, including the lake and most of its floodplains, falls into the Zones 1 and 2. The diagonal lines indicate the extent of flooding in year 2000 when the flood was exceptionally high (Figure 4).

Database Analysis

Database analysis included reviews and analyses of different socio-economic and related databases as well as the creation of a new topographic-based socio-economic database for the Tonle Sap Area. The socio-economic indicators included in the new database consisted of various socio-economic indicators, such as age, population, literacy, occupation, land use, poverty and use of natural resources. The most important database was the Population Census 1998 (NIS, 2000) that contained data from all 1158 villages within the study area. Other databases included the Fishing Household Survey (FHS) from years 1995–96 (COMBASE, 1996), the Poverty Mapping Database from 2002 (WFP, 2000), and the Land Use Database (JICA, 1999).

The lack of more recent databases means that the database analysis is partly out-of-date, increasing further the importance of village surveys and other information sources to complement and contradict the results of the database analysis. The results from the Inter-Censal Population Survey of 2004 generally supported the results of the Population Census 1998, but also showed considerable improvements in several fields in country-level (NIS, 2004). The proportion of employed people working in the agriculture, hunting, forestry and fishing sectors in 2004 was slightly less (74%) than in 1998 (77.5%) but still remained extremely high.

Tables 2 and 3 present information about selected social and economic indicators in different zones derived from the constructed database. For more detailed information on different socio-economic variables and their analysis, see Keskinen (2003).

Table 2. An example of selected social indicators of different zones

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	All zones
0–19 years	56.0%	58.3%	57.0%	56.6%	53.4%	55.9%
Females	50.6%	52.0%	52.2%	52.3%	51.9%	52.0%
Literacy rate	35.7%	44.3%	48.9%	51.2%	66.0%	52.9%
Ethnic origin (FHS)						
Khmer	82.9%	100.0%	99.8%	94.9%	100.0%	94.6%
Chinese			0.2%	0.1%		0.1%
Vietnamese	14.0%			0.9%		3.0%
Cham	3.0%			3.9%		2,2%

Source: NIS (1998); COMBASE (1996).

Table 3. Main occupational involvement in different zones

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	All zones
Census 1998						
Agriculture	26.1%	91.0%	83.5%	77.0%	21.5%	63.4%
Trade	10.3%	2.1%	4.9%	8.3%	30.2%	12.0%
Fishing	55.2%	2.1%	2.4%	1.4%	0.6%	5.7%
FHS 1995–96						
Farming	17.1%	86.9%	86.5%	76.4%	31.7%	67.2%
Fishing	60.9%	3.6%	3.8%	6.4%	6.3%	15.5%
Trade combined	8.0%	1.2%	2.5%	4.4%	28.5%	5.3%

Source: NIS (1998); COMBASE (1996).

Participatory Village Surveys

Participatory village surveys together with database analysis formed the foundation of socio-economic analysis. Village surveys were based on the methods of the Rapid and Participatory Rural Appraisal (RRA and PRA). The main difference between the two is that in the RRA the aim is to apply participatory methods to gain information whilst minimizing biases, while the PRA is a more long-term process with an emphasis on knowledge sharing and empowerment of local people (Chambers, 1994). Due to the nature and scope of the WUP-FIN Project, the village surveys were used to gain better understanding of the local realities and were not for long-term development of the survey villages as such. Therefore, the approach of the village surveys is inevitably more extractive and closer to RRA than PRA. However, this should not also prevent the use of so-called PRA methods to benefit both the project through a better understanding of the local situation, and the villagers through enhanced, although still limited, participation in the analysis process.

There are several examples of the use of local knowledge and participatory research methods to benefit water resources research. For example, the experience of Valbo-Jørgensen & Poulsen (2001) illustrates that local fishermen can be an extremely valuable information source when studying fish migrations in the Lower Mekong Basin. However, in a context as large and complicated as the Tonle Sap, the local knowledge is best utilized when combined with information gained from other sources, since the combination of scientific and local knowledge usually exceeds the limits of either type of knowledge alone (Zanetell & Knuth, 2002).

Altogether six participatory village surveys were conducted in five provinces around the Tonle Sap. In order to capture the seasonal and topographic variation, the village surveys covered all four topographic zones (Figure 1), and took place during both the dry and wet seasons. Each village survey lasted approximately four days and involved 15–20 villagers of different ages, gender and occupations (Figure 2). The village survey reports were prepared in both Khmer and English. Reporting in the local language as well as making the reports freely available on the project's website were regarded to be important ways of enhancing the possibilities of participation for local people and other stakeholders.

Participatory methods used in the village survey were in chronological order:

- key-informant interview (semi-structured interview);
- group discussion (semi-structured interview);

Figure 2. Seasonal ranking in Preak Ta Kong Village. *Photo:* Marko Keskinen.

- participatory mapping;
- transect walk and observation;
- seasonal calendar and occupational preference ranking;
- time ranking;
- focus group discussion and ranking on migration; and
- final discussion and analysis of the survey.

The key-informant interviews were performed at both the provincial and village level. Their aim was to collect overall information about the socio-economic situation in the area, and to better link the village survey with the other projects and actors in the area. The actual participatory methods encompassing group discussions and different mapping and ranking exercises focused on livelihoods, use of natural resources and their trends. Understanding the recent and probable future trends was seen as extremely important due to the dynamic nature of social and economic issues.

In the synthesis report (Keskinen, 2003), the findings of the village surveys were combined and compared with the results of database analysis and literature reviews. To make the comparison of achieved qualitative information easier, part of the survey results were 'semi-quantified' with the help of symbols or diagram charts. Table 4 shows an example of the result of the time rankings that are summarized and 'semi-quantified' as symbols representing trends.

Results of the Socio-economic Analysis

The socio-economic analysis combined information derived from the database analysis, participatory village surveys and other information sources such as literature reviews and expert interviews. The analysis was performed separately for each zone in order to

Table 4. Trends of different environmental and socio-economic variables in the survey villages

	Kampong Preah (ZONE 1)	Preak Ta Kong (ZONE 4)	Ansang Sak (ZONE 2)	Kampong Pradam (ZONE 3)	Peam Kraeng (ZONE 3)	Pou (ZONE 1)
Population	↗	↗	↗	↗	↗	↗
Level of livelihood	↘	↘	↘	↘	↘	↘
Fish catch	↘	↘	↘	↘	↘	↘
Area of flooded and other forest	↘	↘	↘	↘	↘	↗
Availability of agricultural land		↘	↘			
Amount of cattle		∿	∿	↗	↗	
Flooding	↗	↗	↘	↗	↗	↗
Water quality	↘	↘	↘	↘	↘	↘
Sedimentation	↗		↗	↗		↗

understand each zone's specific characteristics, and consequently, to see the differences between the zones in terms of socio-economy, land use, natural resources and vulnerability to the possible changes in water resources. Table 5 summarizes the basic socio-economic characteristics for each zone.

People living closest to the Tonle Sap Lake are in many ways in a worse situation than those living closer to the National Roads. They are generally poorer, less educated, have fewer livelihood options, do not own agricultural land and largely depend on common property resources such as water bodies and flooded forests for their livelihood (Keskinen, 2003). Ethnic issues are also important because many of the floating villages are inhabited by ethnic Vietnamese whose status in the country remains unclear and is often unrecognized.

People living in the rural zones further away from the lake rely heavily on rice cultivation for their livelihood, and decreasing availability of agricultural land due to population growth is therefore among the main problems in this area. The villagers depending on the cultivation of floating and recession rice are particularly vulnerable to the changes and year-to-year variations in floods. Although people living in these zones are generally wealthier than those living on the lake, economic disparity seems to be greater. This also indicates possible conflicts in the future.

There is a clear occupational difference between the zones. The urban zone naturally forms a very different case with its more diverse livelihood structure. The rural zones can be classified into two different main groups: the fishing zone (Zone 1) and the agriculture zones (Zones 2–4). While fishing forms the main source of livelihood in Zone 1, rice cultivation and other agricultural activities are by far the most important source of livelihood in all other rural zones. Secondary occupations form an important supplement for the main occupations in all rural zones, particularly during the seasons when involvement in the main occupation is less intensive. Fishing is among the most important secondary occupations in all agricultural zones.

Table 5. Basic socio-economic characteristics of each zone

Zone	Basic socio-economic characteristics
Zone 1	Mostly floating villages; main industry fishing with some involvement in trade; lowest level of livelihood; highest incidence of ethnic minorities, particularly of Vietnamese; lake and flooded forests & shrubland; severe flooding
Zone 2	Main industry rice cultivation and particularly floating and recession rice; part-time involvement in fishing significant; flooded shrubland and abandoned / partly used fields; severe flooding
Zone 3	Main industry rice cultivation; involvement in fishing less significant than in lower zones; most of the area covered by permanent rice fields; regular floods important for rice cultivation; moderately flooded
Zone 4	Main industry rice cultivation; growing importance of other industries (commerce & manufacturing); better access to the markets and higher level of livelihood than in other rural zones; most of the area covered by permanent rice fields
Zone 5	Occupational involvement in the village level more diverse but within households less diverse than in the rural zones; highest level of livelihood and education; most developed infrastructure and best market access

The clear occupational division is particularly significant when it is recalled that a large majority of the people in the survey area live in Zones 3–5. Hence, although the Tonle Sap Lake itself is particularly known for its exceptional fish production, most of the people living in its floodplains are actually more dependent on agriculture than aquatic resources for their livelihood. However, it must be remembered that although it is not the primary source of livelihood in the area, fish has a very special role in Cambodia: it is the staple food for the entire country, and the main source of income particularly for the landless and the poor in many areas (Gum, 2000).

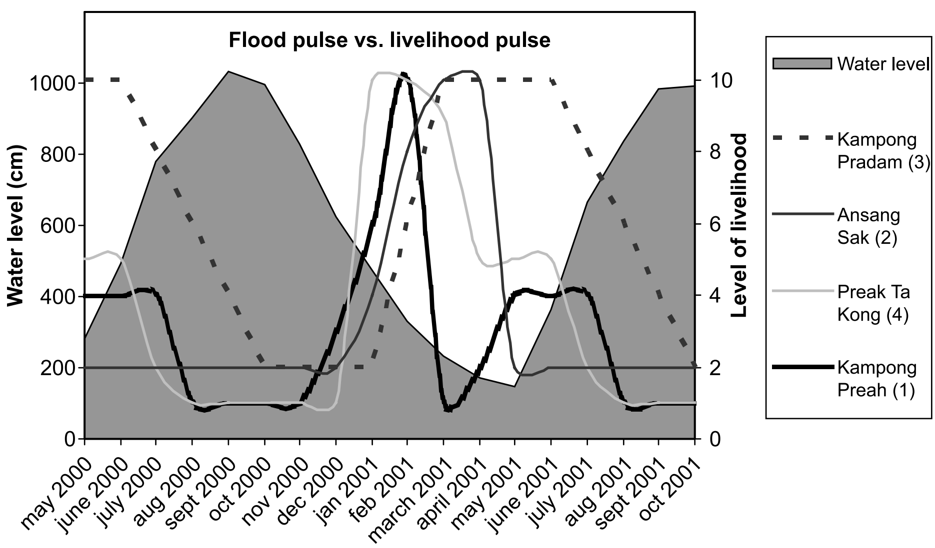

Figure 3. In Tonle Sap the annual flood pulse is followed by a so-called livelihood pulse

Table 6. Comparison between data drawn from Population Census and Village Survey results

Village (zone)	Population Census 1998			Village Surveys 2002–03		
	Households	Fishing	Agriculture	Households	Fishing	Agriculture
Kampong Preah (1)	172	417	130	115	Majority	Little, part-time
Prek Ta Kong (4)	45	0	98	45	1 family	Majority
Ansang Sak (2)	158	4	193	205	9 families	Majority
Kampong Pradam (3)	188	0	490	227	26 families	Majority
Peam Kraeng (3)	262	0	616	271	Part-time	Majority
Pou (1)	55	122	6	84	Majority	No

The results of the socio-economic analysis indicate clearly that the livelihoods of the population in the Tonle Sap Area are very closely connected with annual hydrological cycle of the lake. Adaptation to, rather than control of, the area's exceptional water regime is therefore a typical characteristic in the Tonle Sap; the situation is exactly the reverse, for example, in the Mekong Delta of Vietnam. Figure 3 shows a somewhat simplified representation of the relationship between the water regime and level of livelihood by presenting the annual variation of both together. The dark grey area in Figure 3 shows the water level in Kampong Level measurement station in the years 2000–01 when the floods were exceptionally high. Four lines indicate the seasonal variation of the level of livelihood as derived from the seasonal calendar exercises in four survey villages. Kampong Preah is a fishing village with floating houses while all other villages are agricultural villages located in different topographic zones shown in parentheses.

From Figure 3 it can be clearly seen how the flood peak in September–October is followed a few months later by a rapid increase in level of livelihood, 'livelihood pulse', in all four villages. This is due to two main facts. First, receding floods results in a massive migration of fish from the floodplains to the lake and finally to the Mekong River. This period is also the most productive fishing period of the year. Second, the main rice crop is harvested every year few months after the flooding has brought water and fertile silt to the rice fields. Figure 3 thus also shows the strong seasonal nature of the level of livelihood, particularly due to the much higher importance of primary livelihood sources compared with secondary and tertiary sources.

The significant dependency on natural resources and water in the Tonle Sap Area is particularly alarming since the products from several natural resources seem to be in decline. For example, the fish catch from the Tonle Sap River's *Dai fisheries* decreased for three consecutive years 2002–04 and in 2004 it was the lowest ever recorded (Hortle *et al.*, 2004). At the same time it should be noted that the fish catch of 2005 was exceptionally high, and that the overall reliability of fisheries statistics in the area can be seriously questioned (Lamberts, this issue). Nevertheless, the decreasing trend seems clear and the decrease in availability of natural resources and rapid population growth is an unsustainable combination that is likely to decrease the level of livelihood, particularly in the rural areas. The result of this will probably be a large increase in the number of people migrating to urban areas (Heinonen, 2006, this issue).

It is also important to note that the occupational diversity in the Tonle Sap Area is much greater within households than within and between the villages, as the main source of livelihood in each village and commune appears to be surprisingly uniform. This increases people's vulnerability to the sudden environmental changes: if the primary source of livelihood fails, the secondary livelihood sources, often regarded as the safety net of the villagers, cannot sustain the sudden load created when most of the people in the village shift simultaneously to these sources.

The combined approach that made use of both the databases and the village surveys also offered the possibility for comparison and cross-checking, revealing shortcomings of both methodologies. Table 6 presents a comparison between information derived from the Population Census and village surveys. As can be seen, the information from these two very different sources is mostly consistent, but clear inconsistencies also emerge, for example, in the first survey village. Closer analysis of these differences

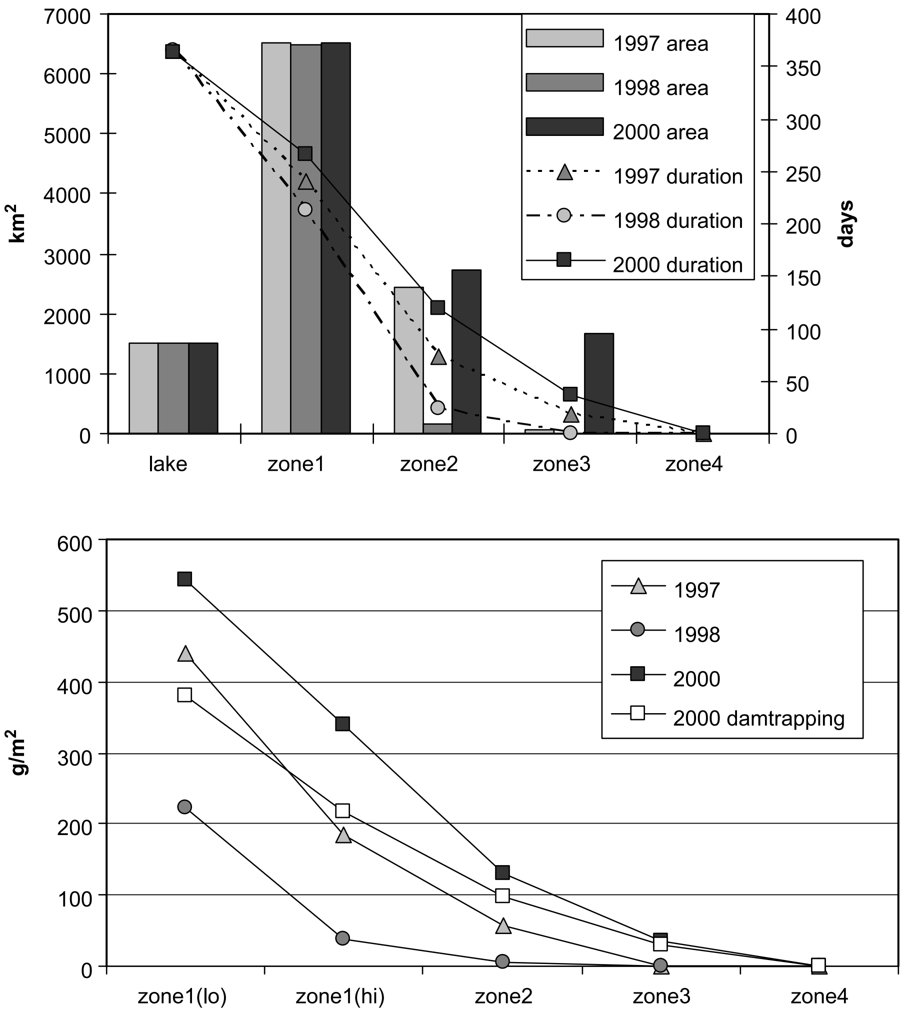

Figure 4. Flooded area and average sedimentation in different zones.

revealed some in-built problems the Population Census' enumeration related to, e.g. seasonal migration (Keskinen, 2003). These problems and discrepancies in the databases could thus be taken into consideration when carrying out the socio-economic analysis.

Integration of Socio-economic and Hydrological Information

How does the topographic zoning and semi-quantification of village survey results actually facilitate integration with water modelling? While the zones formed practical and convenient entities that are relatively uniform in their socio-economic characteristics, semi-quantified village survey results made the comparison of survey results with database analysis easier. Since the model results can also be presented according to the defined zones, these both benefited significantly the integration between the socio-economic analysis and modelling.

Figure 4 presents an example of the model results derived from hydrodynamic and water quality models developed for the Tonle Sap Lake. The left-hand diagram shows the extent of flooded area and the flood duration while the right-hand diagram demonstrates the variation in sedimentation in different years. The sedimentation diagram also includes a so-called 'dam-trapping' scenario where the sediment load from the Mekong River to the Tonle Sap has been halved to illustrate the possible effect of upstream dam construction to the sediment influx.

Figure 4 shows remarkable differences in the area and duration of flood between the different zones. These changes are particularly extreme in Zones 2 and 3 where all floating rice cultivation and most of the other rice cultivation are concentrated. Sedimentation, which is seen as one of the main driving forces for fish production (van Zalinge *et al.*, 2003) and an important nutrient source for agricultural land, also greatly varies between the different years and zones. Therefore, these changes will probably have an enormous, and varying, impact for the people living in different zones. For more information on model results and integration, see Kummu *et al*. (2006, this issue) and Nikula (2005).

Although this kind of quantitative integration with the help of GIS facilitated linking between socio-economic and hydrological information, it proved not to be enough to understand thoroughly the intricate interconnections between hydrology, environment and social and economic aspects. The main reason for this is the lack of suitable quantitative data: most of the interconnections remain poorly understood and analysed, and many of them cannot anyhow be presented comprehensively in quantified terms.

Consequently, integration between socio-economic, environmental and hydrological information was further facilitated with so-called descriptive integration utilising both quantitative and qualitative information (Nikula, 2005). The idea is first to identify the most relevant hydrological indicators (e.g. flood level), then define the mechanisms that their potential changes cause (e.g. increased flood area), then recognise their most important ecological impacts (e.g. fish production), and finally consider impacted livelihood activities, together with the immediacy that the impact is felt. This entire 'impact process' is presented with so-called impact tables, where the direction and intensity of the impacts are specified based on data, information and knowledge available for this specific impact. An example of such an impact table is presented in Table 7. For more information on integration, please refer to Kummu et al. (2006, this issue) and Nikula (2005).

Table 7. Example of impact table for Tonle Sap (Nikula, 2005)

			mechanism		impact	impacted livelihood activity	impact immediacy
Maximum flood level	low	► 1	decreased availability of inundated habitats in the floodplain	- →	fish productivity	fishing	within the same season
	low	► 2	decreased sedimentation > decreased nutrient supply	- (a) →	soil fertility and primary productivity > availability of agricultural, aquatic and forest pruducts	agriculture, fishing, gathering	after a few years
	(a) locally heavy sedimentation may hamper agriculture or fishing						
	low	► 3	drought problems on rice fields	- →	success of rice harvest	rice cultivation	immediate
	low	► 4	less flood damages on rice fields	+ →	success of rice harvest	rice cultivation	immediate
	high		In case 1 opposite change in indicator (higher max flood level) would probably lead in opposite impact (higher fish/aquatic productivity), as would in case 3.				

Conclusions

This paper presented the experiences from the water-related socio-economic analysis within the Tonle Sap Modelling Project, and studied them in the context of the Integrated Water Resources Management. It is argued that modelling can have an important role in integrated management of water resources, particularly in an area as complex and multifaceted as the Tonle Sap Lake. However, in order to meet the ambitious and multidisciplinary demands of integrated management, the entire approach of modelling has to be updated as well: modelling projects must link their work better with the other dimensions of water management, most importantly with society where its linkages have traditionally been the weakest. Water-related socio-economic analysis proved to be a helpful tool in this as it improved the understanding of the most significant water-related problems, and thus enhanced the linking of the model results with social and economic issues.

The experience from the Tonle Sap illustrates that the socio-economic analysis benefits from an approach combining quantitative socio-economic databases with more qualitative, participatory research methods. While database analysis worked well on a macro-scale in different topographic zones, it had several biases and deficiencies at the village level. Respectively, the participatory village surveys fundamentally increased the understanding of the most relevant socio-economic issues at the village level, but could not form a comprehensive picture from the entire area due to their small sample. The two methodologies thus formed an advantageous match by supporting and complementing each other.

The integration between socio-economic and hydrological information was made easier by analysing both the socio-economic databases and village survey results according to topographic zones, instead of administrative boundaries. This facilitated linking the analysis results with the lake and its floods, and consequently, with the developed water models. Even then the integration remained partly incomplete due to lack of information on ecological processes and functions such as fish and rice productivity that connect people's livelihoods with water. More on integration, ecology and its challenges can be found at Nikula (2005).

Participation of local people also proved to be crucial for the integration work, because local people provide invaluable insights in the interconnections between water, environment and society. The complexity of the water-environment-society relations and the lack of scientific data make their analysis utterly challenging, and the local knowledge can help to shed some light on this complexity. With more focused participatory exercises such as a comparison exercise between different types of floods (e.g. Hardner *et al.*, 2002), this type of knowledge could be even more beneficial. Through participatory methods the needs and expectations of local people could also be taken into account more comprehensively, which paves the way for more balanced management.

There are naturally several aspects that could be improved. The socio-economic team could have been even more multidisciplinary, with experts from the fields of water resources management, rural development, fisheries and GIS. In addition, the socio-economic analysis was focused on issues of livelihoods, giving less thought for other important social and economic aspects such as health, gender and cultural values. In addition, participation of local people should be improved, despite challenges related to, for example, the technical nature and the scale of the project, particularly in the final phases of the analysis.

Although the socio-economic analysis of the WUP-FIN Project was carried out with relatively few resources and a tight timeframe, it provided invaluable information that improved the linkages between modelling, environment and society. It helped to focus the modelling better into the real issues at both grassroots and higher levels, and thus also made the model results more useful and applicable for planners, managers and decision-makers. The socio-economic analysis increased the possibilities for local people to participate, an aspect that is often neglected in modelling projects, and consequently enhanced the understanding of local realities. This understanding is extremely important, not only for the success of modelling but also for the success of the IWRM as each region has its own specific characteristics that have to form the basis for the management of the region's water resources. This is particularly applicable for the Tonle Sap Area with its extraordinary water regime, exceptional ecosystem and intricate social conditions.

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