Northeast Thailand Futures: A Local Study of the Exploring Mekong Region Futures Project

FINAL REPORT

July 2010 –October 2012

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List of Acronyms

ACMECS	The Ayeyawady-Chao Phraya-Mekong Economic Cooperation Strategy
AusAID	Australian Government's Overseas Aid Program
BBN	Bayesian Belief Network
CSIRO	Australian Commonwealth Scientific and Industrial Research Organization
DGR	Department of Groundwater Resources, Thailand
DOAE	Department of Agriculture Extension, Thailand
DWR	Department of Water Resources, Thailand
EPPO	Energy Policy and Planning Office, Thailand
GHG	Greenhouse gas
GMS	Greater Mekong Sub-region
HSB	Huai Sai Bat sub-basin
KKCRMUTI	Rajamangala University of Technology Isan, Khon Kaen Campus
KKU	Khon Kaen University
LDD	Land Development Department, Thailand
NE	Northeast (meaning northeast Thailand or Isaan region)
NESDB	Office of the National Economic and Social Development Board, Thailand
RBCs	River Basin Committees
RID	Royal Irrigation Department, Thailand
SEA START	Southeast Asia START Regional Center
SEI	Stockholm Environment Institute
SRBCs	Sub River Basin Committees
SRES	Special Report on Emissions Scenarios
TAO	Sub-district (or Tambon) Administration Organization
TMD	Thai Meteorological Department
WEAP	Water Evaluation and Planning System

Executive Summary

Continually increasing energy and food demands are driving a marked change of land-use in Northeast (NE) Thailand, especially in terms of growing rice, sugarcane, cassava, and rubber. As the long-term country energy policy continues to promote ethanol and biodiesel, the trend is for local farmers to alter their food cropping regime and switch to either sugarcane or cassava. To help explore future farming activities and examine the potential implications to the livelihoods of people in NE Thailand, this local study, led by the Stockholm Environment Institute (SEI) and Khon Kaen University (KKU) in collaboration with the Department of Water Resources (DWR) Region 4 and Rajamangala University of Technology Isan, Khon Kaen Campus (KKCRMUTI), aims to introduce multi-objective oriented planning to create planning scenarios and design appropriate policies through ongoing planning processes led by the River Basin Committees (RBCs) and Office of the National Economic and Social Development Board (NESDB). The RBCs are the target stakeholders and have played an active role in designing the scope of work and participating in various study activities. As strongly recommended by the RBCs, the Huai Sai Bat (HSB) sub-basin in the Chi river basin was chosen as a study area rather than the whole NE Thailand region. To officially contribute to the study, a working group of the NE Thailand Futures local study, consisting of 27 representatives from concerned agencies, was established by the Chi RBCs and became an active driving body.

In terms of study approach, this study has drawn upon multi-sector planning processes. The approach features participatory scenario processes within the NE, framed by larger-scale scenarios. The NE-level scenarios took these larger processes into account and added uncertainties at the local level. Key information was derived from both quantitative and qualitative data collection methods, with participatory inputs by a wide range of stakeholders. The qualitative scenarios have been used to inform integrated quantitative scenarios using a combination of physical and social science models. A combined top-down physically-based model (Water Evaluation and Planning System or WEAP) and bottom-up livelihood model (Bayesian Belief Network or BBN) has been used. In addition, a livelihood survey, meetings and trainings organised for the stakeholders, as well as four local study workshops were conducted. Through the first two scenario building workshops, a set of key drivers of change were identified, and four realistic 'visions' of the HSB area in the future were jointly produced by the workshop participants. In the third and fourth workshops, the participants discussed the validity of hydrological and livelihoods research results and potential policy implications. Their feedback has served as guidance for the finalization of the hydrological and livelihoods analyses and modelling (using WEAP and BBN), the results of which are included in this report.

The local study involved a survey of 400 households and two focus group discussions in HSB to investigate the current local situation, problems, future trends, and stakeholder opinions regarding the river basin. Issues investigated were designed around the key drivers of change for development identified during the first scenario building workshop, which were: climate variability and/or climate change and its impacts; water management and/or water competition; land-use and agricultural systems change; profit from crop cultivation; people's participation in decision-making processes; and energy demand, development projects and market access. From this field work, it was found that the main livelihood pursuit in HSB is agriculture, and supplementary jobs are provided through wage labour, livestock raising, and retail trading. HSB households have lower than the average household income in NE Thailand. The majority of households own their own land and use it for growing mainly rainfed food crops. Households with access to irrigation mainly grow a second crop of rice in the dry season. In recent years, increases of irrigated areas have led to problems of water competition among users, especially for dry season rice. Moreover, climate variability is believed by respondents to cause problems, specifically more frequent water shortages in non-irrigated areas and a higher frequency of water resources (e.g. rivers/streams) drying up. The water supply for domestic and agricultural production in the dry season is insufficient.

Another driving force investigated is crop price. High prices for a particular commodity tend to increase the growing area of that crop (e.g. sugarcane, cassava and rubber) in HSB. However, a majority of the respondents believe that there will not be a significant change from growing food crops to energy crops in the long-term future. Diverse opinions on this finding were widely discussed by participants at the 3rd local study workshop. In terms of migration for work, those who have higher education qualifications are likely to migrate to work outside the agricultural sector. Despite this challenge, agricultural labourers are still available within the community, but the labour cost has increased. Further, access to markets has been increasing because agricultural factories have entered the NE region. The majority of people surveyed believe that they will gain more benefits from export markets arising from various regional development projects, but do hold some concern regarding foreign competitors. The energy demand in the area is increasing in both agriculture and in household consumption; thus, household representatives would like to see more earnest support for renewable energy from the government. It was also found that people's participation in decision-making in development projects has been increasing compared to the past, but is still not very effective or adequate, and stakeholders would like to be further involved.

In a region which already faces water shortages and uncertainty in agricultural production, an assessment of the catchment's ability to satisfy its future water demand is essential for future development planning. WEAP, a Windows-based modelling tool for integrated water resources management and policy analysis, was applied in exploring the effects of different drivers on future water demand and availability in the HSB sub-basin from 2010 to 2030. The anticipated changes in the sub-basin chosen for this investigation were land-use change, climate change, and the development of water resource infrastructure. For land-use change, scenarios illustrating various changes in crop type (rice to sugarcane, non-irrigated to irrigated crops) were modelled. Results from WEAP show that streamflow and unmet water demand are not significantly affected in these scenarios. However, unmet water demand does significantly increase with an expansion in the area of irrigated rice and other crops in the catchment. The modelling of climate change effects was based on the A2 (high greenhouse gas (GHG) emissions) and B2 (low GHG emissions) Special Report on Emissions Scenarios (SRES) regional emission scenarios. WEAP shows that both climate change scenarios double annual streamflow in the HSB catchment, especially increasing it from June to August, with a higher possibility of substantially increased catchment runoff. Two scenarios of water resource infrastructure development were also explored: the potential large-scale diversion of water to the HSB catchment for irrigation under the Kong-Loei-Chi-Mun project, and a combination of small-scale irrigation changes and construction of water storage areas in response to local increased demand. WEAP demonstrates that additional water transferred from the diversion scheme can significantly affect the water balance and fully satisfy the increased water demands from the expansion of the irrigation (through transforming all rainfed areas (rice, sugarcane and cassava) into irrigated areas, and increasing irrigation to fully cover the sub-basin's needs). For the small-scale water storage scenario with additional water storage of 40% of total runoff in each sub-basin available, it can transfer water from the wet season to supply to dry season crops to a certain extent. However, it is still insufficient to fulfil all additional water demands required for expanding irrigation to all existing rainfed areas (rice, sugarcane and integrated farm) especially in upper sub-basins that are already under water stress. This leads to significant reduction in stream outflow. However, a less extreme change in land-use will have a smaller effect.

The study also explores the effects of changing incentives for growing different crops on land and water resources, as well as poverty and livelihoods, in the HSB sub-basin. NE Thailand is expected to undergo land-use change as biofuel production is increasingly incentivized by the Thai government. At the same time, changing income levels due to economic growth in Thailand is assumed to lead to changes in land-use decisions by farmers in the HSB sub-basin. The BBN model in this study uses a calculated income distribution and the results of a household survey in rural HSB to investigate the impact of such a change in income distribution on the transition from food crops to energy crops or mixed cropping systems. The linking of the BBN and WEAP models relates land-use change to changes in agricultural water use and other hydrological processes. Results of the household surveys reveal that higher-income households diversify their crops more than lower-income households; they also diversify into non-agricultural activities more. Using these assumptions, scenarios of stable, growing and decreasing income inequality were run. The effects of income inequality on poverty are found to be modest despite continued economic growth, even when income inequality drops toward the national average. Impacts on land-use and hydrology are also modest, with little change seen in land cover and streamflow between different income inequality scenarios. These results are based on the assumed continuation of past trends, such as the tendency toward smallholder farms; any future deviation from past trends may therefore provide results that are significantly different from this study.

The local study project team has successfully engaged in ongoing policy planning processes led by the NESDB and regional RBCs, who consented to the project and approved its concepts since the inception stage. In the northeast regional meeting held by the NESDB in March 2011, one project team member, Dr. Yanyong Inmuong, was invited to lead a forum on the proposed framework for natural and environmental resource development for the 11th five-year National Economic and Social Development Plan. He highlighted issues such as food-energy crop balance and climate change risks, which led participants to propose the inclusion of food and energy resource issues in the five-year plan framework. The need for planning tools in the food and energy sectors was also raised, highlighting potential use for the water-food-energy nexus modelling tools from the HSB study. Members of the Chi RBC also benefited from collaborating with the local study through WEAP and BBN model workshops and trainings. The Chi RBC introduced the water-food-energy nexus concept into their three-year strategic water resources development plans in September 2011, which has further influenced the annual regional and provincial water resources development action plan.

From the results of the household survey, focus group discussions, hydrological and livelihoods analysis and modelling as well as consultations with various concerned stakeholders, the project team proposes the following recommendations related to the policies, capacities and other concerned supports for development of future NE Thailand in general, and for the HSB region in particular.

Future agricultural policies and economic growth are likely to affect crop choice. The following factors should be considered: (1) whether anticipated changes are likely to significantly affect the water balance in the basin, and (2) whether current shortage can be met or alleviated with the water resources in the basin. There are poverty strategies that do not significantly affect the water balance, and current shortages can be alleviated using the water resources in the basin to some extent. Water resource development plans should include promoting small irrigation projects in farmlands and villages as far as possible. This can encourage the feeling of ownership of the local communities, relies on water resources within the sub-basins, and thus tends to lead to more sustainable project implementation in the longer term.

Regardless of the impact of biofuel promotion policies on land and water, levels of inequality and land ownership can significantly affect poverty and livelihoods. Even if poverty declines, income inequality can remain quite high if economic growth is strong enough. This suggests that in future planning for regional economic growth, careful attention should be paid to the distributional impacts of different policies. To the extent possible, strategies that promote economic growth while also reducing inequality would be preferable.

Another recommendation for future policy development from participants and researchers of this study is the initiation of a climate information support system and a local database to help government officials, committees and farmers make more informed and environmentally sustainable decisions. The study recommends research into optimizing income for families at the farm scale and managing farm resources to improve yield and sustainability. In addition, government agencies should support poorer farming households by creating more off-season jobs locally.

The study also found the need for land-use policies that promote forest and biodiversity conservation and restoration. To combat further degradation of poor soils, the national government should promote soil fertility improvements by educating farmers on soil, water and forest conservation and the impacts of agrochemicals, as well as promoting the use of organic fertilizers.

The HSB study team interviewed six partners representing different key stakeholders who had participated in the local study activities on the most significant impacts from their experiences, and why they considered those impacts significant. These stakeholders are leaders from various offices and organizations that hold different perspectives, such as the NESDB, the HSB Working Group, and the Kong-Chi-Mun RBCs. The stakeholders reported that through their participation in the local study activities, they realized the importance of policy development based on scientific research and became aware of the use of modelling tools in planning for the future. They also emphasized the need for: collaboration between different sectors and countries; inclusion of local participation and input; and highlighting common goals between different organizations for more successful project implementation.

CHAPTER 1 Introduction

Authors: Chayanis Krittasudthacheewa, Eric Kemp-Benedict, Yanyong Inmuong and Angela Bush

1. Background

The Australian Commonwealth Scientific and Research Organization (CSIRO) and the Australian Government's Overseas Aid Program (AusAID) are supporting national and regional decision making processes on complex issues in Mekong countries through the project Exploring Mekong Region Futures, which investigates the water use, food security, and energy supply nexus by providing integrated, alternative, scenarios of future development. According to the scoping in 2009, five proposals were selected to undertake studies in five specific locales: Yunnan province of China; southern Laos; northeast (NE) Thailand (also known as Isaan); the Tonle Sap area of Cambodia; and Vietnam's Mekong Delta.

NE Thailand is an important local study area due to its large population as well as being the most impoverished agricultural region in the country. Isaan has been a top priority for national development schemes, which have improved household living standards dramatically in the last few decades (Barnaud et al., 2006, Rigg and Salamanca, 2009). Despite this achievement, household incomes in the region continue to depend heavily on agricultural commodities and livelihoods. Continually increasing energy and food demands are driving a marked change of land-use in NE Thailand, causing expansions in areas where sugarcane, cassava, and rubber are grown.

As most soil is degraded, the NE crops normally produce markedly low yields as compared to other regions. One third of the NE land is saline soil. The resulting intense use of chemical fertilizer, especially in contract farming, is leading to more polluted land and water, contributing to a decline in the fishery resource in natural waters. Poor farmers cannot find natural fish for food, and competition for land and water among NE farmers has become very common. As the long-term country energy policy promotes ethanol and biodiesel production, local farmers alter their food cropping regime by changing from highland rice to either sugarcane or cassava.

Converting land for either food or energy is becoming a critical issue, with no common agreement and understanding among policy-makers or rural farmers. Climate change in this area is predicted to result higher rainfall with short periods, causing floods that can destroy agricultural lands, while rather longer dry periods increase irrigation demands. Rivers experiencing low or no flow cannot supply enough water to cropped lands, and this will eventually cause conflict among farmer groups and government officials. Climate variability, with a shorter wet season but long dry period, will also likely make many farmers switch to growing crops off the seasonal regime with supplementary water. This increases tensions over the use of natural waters. The provinces of Isaan situated along the Mekong river with enough rainfall, are heavily dependent on rubber plantations. These and other NE farmers who grow commercial plants feel insecurity over fluctuations in the price of those crops on the world market. This insecurity can cause farm owners to leave their land to seek additional income outside Isaan, contributing partly to social problems – broken families, declining family health, illegal migration, and rising crime – which are therefore increasing. A clear understanding of the interconnected food-energy-water issues in NE Thailand is challenging, but critical to achieve.

The NE region faces challenges in its future development as put forward by the Greater Mekong Sub-Region (GMS) and the Ayeyawady - Chao Phraya - Mekong Economic Cooperation Strategy (ACMECS) roadmap. These challenges are driven by dynamics within the country, and the rising concern of energy, food production and logistics for key development areas. Major forces of change in the NE currently are: changing land-use for re-targeting to commercial crops, increasing production of energy crops, labour migration (from Laos and Cambodia to the NE farmlands and services and out migration of Thai locals for better wages to outside the area), and importation of hydropower.

2. Local Study Objectives

This research study aimed to help develop participatory scenario processes for NE Thailand, framed by larger-scale (national and Mekong) contexts and possibilities. These include changes in hydrology (e.g. infrastructure development and climate change), land-use change, and regional migration dynamics. The results of the study informed the River Basin Committee (RBC)'s planning processes by introducing multiple-objective oriented planning, which enabled the creation of planning scenarios for multi-stakeholder debate and informed the analysis of policy and related decisions.

The study engaged the central national policy-making body, NESDB, which establishes the regional development plan. Other national sectoral bodies involved were: DWR, the Department of Groundwater Resources (DGR), the Department of Agriculture Extension (DOAE), the Land Development Department (LDD), and the Energy Policy and Planning Office (EPPO). The officers from the local and NE regional offices of these departments actively participated in study activities to move from single sector-based policies and planning to embrace a more integrated approach for meeting these challenges.

The NE Thailand local study focused on an introduction of multi-objective oriented planning in order to create planning scenarios and enable the design of appropriate policies. The RBCs were the target audiences of the project and played a participatory role with the researchers in practicing the use of planning tools and in scenario-building exercises through qualitative and quantitative data collection and management, consultation meetings and workshops.

The research questions of this local study were:

1 What will be the future agricultural activities in NE Thailand: cropping for food or energy?
2 What does this mean for the hydrology and water resources development?
3 What does this mean in terms of land use change?
4 What are the consequences for the poverty level?

3. Local study outputs and outcomes

Through various activities that the local study team conducted with concerned stakeholders, we helped improve ongoing policy planning process at the river basin level in the short term, which will contribute to planning at regional (NE Thailand) and national levels in the long-term. We achieved this by supporting our stakeholders, especially the RBCs, to gain a better understanding of the interconnection of water, food and energy development and by building the RBCs' capacity for application of planning tools in exploring different development options.

4. Local study team

The Stockholm Environment Institute (SEI) and Khon Kaen University (KKU) in close collaboration with the Thailand DWR, Region 4 and Rajamangala University of Technology Isan Khon Kaen Campus (KKCRMUTI) undertook the work of the NE Thailand Futures local study together.

Key members of this local study from SEI and KKU are:

1. Dr. Chayanis Krittasudthacheewa (SEI-Asia, Bangkok)	Project manager, researcher
2. Assistant Prof. Yanyong Inmuong (KKU)	Head of field team, policy engagement expert
3. Dr. Eric Kemp-Benedict (SEI-US, Boston, USA)	Senior researcher, modeller
4. Associate Prof. Uraiwan Inmuong (KKU)	Field work leader
5. Ms. Jetnapis Rayubkul (KKU)	Field work leader
6. Ms. Orn-Uma Polpanich (SEI-Asia, Bangkok)	Researcher, field work expert, modeller
7. Dr. Angela Bush (KKU)	Researcher, modeller
8. Ms. Phatcharee Seekuta (KKU)	Project assistant, field work expert, analyst
9. Dr. Graham Eagleton (KKU)	Researcher, analyst
10. Ms. Pippa Featherston (KKU)	Researcher
11. Mr. Sopon Naruchaikusol (SEI-Asia, Bangkok)	Research associate
12. Ms. Pin Pravalprukskul (SEI-Asia, Bangkok)	Research assistant

In addition to the key members mentioned above, a working group on the NE Thailand Futures local study, consisting of 27 representatives from national decision-making bodies and concerned line agencies at the regional and local levels, has worked with the study team and has became an active body in directing the study.

5. Boundary partners/stakeholders

The boundary partners with whom the local study collaborated closely and who contributed to the project work are the HSB Sub-basin Committee and Chi RBCs.

Apart from the boundary partners, the project team also engaged other key stakeholders at various stages of local study, e.g. representatives from Kong-Chi-Mun RBCs, the NESDB, leaders of local communities, as well as other concerned agencies.

6. Methodology and study process

The approach of this study drew upon multi-sector planning processes and featured participatory scenario processes within the NE, framed by larger-scale (national and Mekong region) scenarios. The NE-level scenarios took these larger processes into account and added uncertainties at the local level. Key information was derived from both quantitative and qualitative data collection methods, with participatory inputs from a wide range of stakeholders including government departments, development partners and NGOs. This has ensured that the modelling scenarios created are feasible and have the possibility of being accepted by development partners, especially policy and decision makers.

The qualitative scenarios developed were used to inform integrated quantitative scenarios using a combination of physical and social science models. The goal was to create interactive scenario models for decision makers to use in order to expand their thinking about cross-cutting impacts between water, energy, and food, as well as external uncertainties, including climate change. A combination of top-down and bottom-up approach was used, with top-down physically-based model (Water Evaluation and planning System or WEAP) and bottom-up livelihood models (Bayesian Belief Network or BBN).

A combination of desk study, key informant interviews, focus group discussions, household surveys and stakeholder consultations/dialogues were conducted to support qualitative and quantitative scenario development. Local participatory engagement complemented these efforts. A pilot test of the survey instrument was carried out to refine methods that could be used beyond the life of the study. The key concepts that linked the participatory engagement events were the multiple uses of energy and water systems in a context of integrated farming systems. Stakeholders, especially decision-making authorities, were engaged from the onset of the study until outputs were finalised. Through the whole study process and activities, relevant technical capacity of the agencies and universities (including their students) concerned have been strengthened.

The study process of the NE Thailand Futures local study, as compared to the regional study process and the ongoing planning work led by RBCs and the NESDB, is illustrated in Figure 1. Basically, the local study interacts with the regional study continually through communication with the regional team and exchange of information and knowledge during the workshops of both teams. The outputs produced by the local study work were informally fed back into the on-going planning processes led by the NESDB and RBCs, through the participation of our project team member and stakeholders in the NESDB and RBCs formal planning meetings. In these forums, our representatives provided inputs and comments on current development plans or strategies, considering the outputs from the local study.

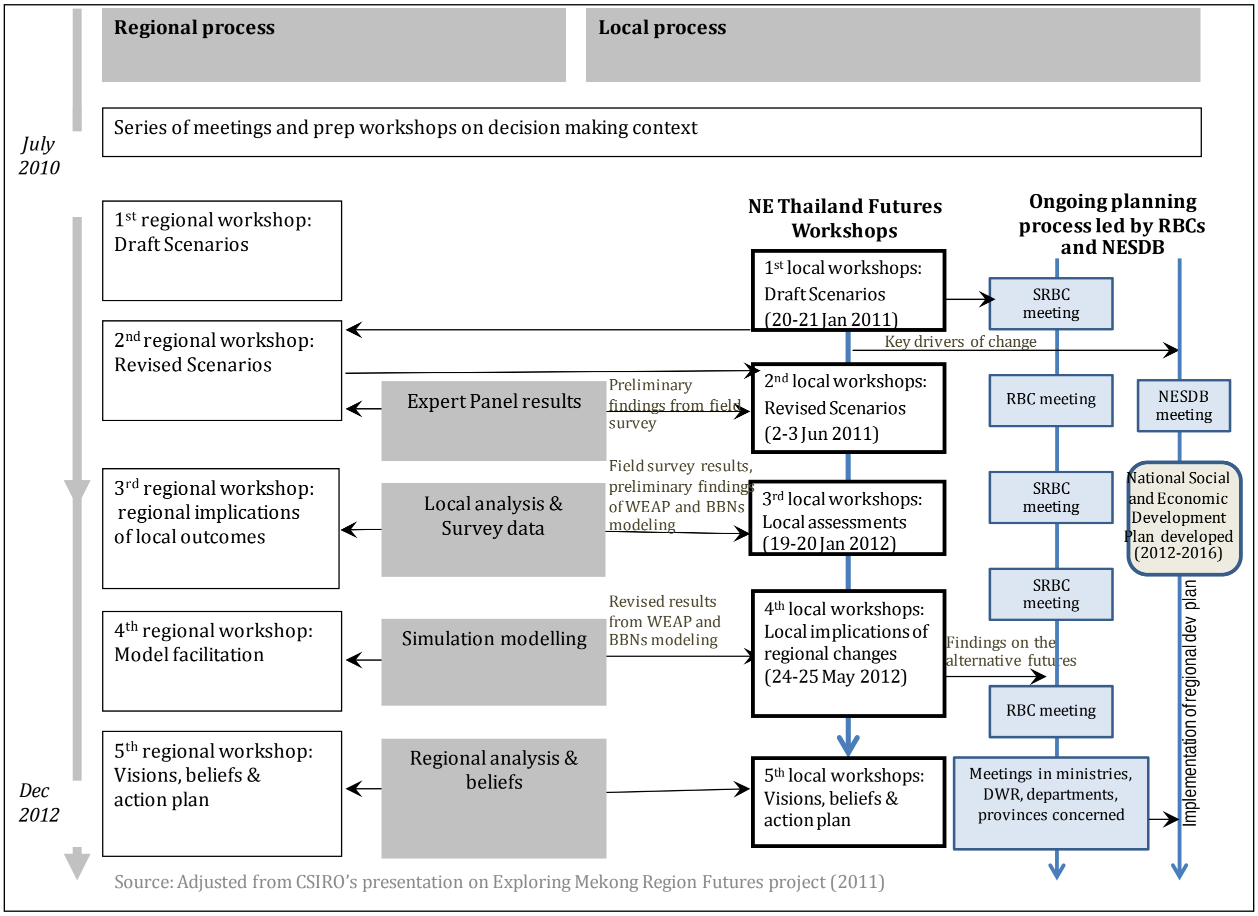

Figure 1: Study process of the NE Thailand Futures local study set against the regional study process and the ongoing planning processes led by the RBCs and the NESDB.

7. References

Barnaud C., Trebuil G., Dufumier M. & Suphanchaimart N., 2006. Rural poverty and diversification of farming systems in upper northeast Thailand. Moussons, 9–10, 157–187.

Rigg J. & Salamanca A., 2009. Managing risk and vulnerability in Asia: A (re)study from Thailand, 1982–83 and 2008. Asia Pacific V iewpoint, 50, 3, 255–270.

CHAPTER 2 Progress of Project Activities

Author: Chayanis Krittasudthacheewa

Below is a description of the progress of the NE Thailand Futures local study activities, from its inception in July 2010 until the end of project in October 2012.

1. Consultation meetings and workshops

- **Inception meeting during 14-15 October 2010:** About 35 representatives from the Kong-Chi-Mun RBCs, technical working group of the Kong-Chi-Mun RBCs and the heads of concerned regional governmental offices participated in the meeting. The meeting aimed to (1) collect comments and suggestions of RBCs, the NESDB and other stakeholders comments regarding the project boundary and activity settings; (2) jointly with RBCs, the NESDB, and other stakeholders, define potential benefits from the local study for development policy and planning system formulation in NE Thailand; (3) discuss potential external and internal drivers causing changes in the management of water and other resources for food and energy further exploration on their feasibility; and (4) seek the opinions of RBCs, the NESDB and other stakeholders on the study area and their support on participatory work with project team members.

  From this meeting, it was concluded that the RBCs will set up a working group to learn and jointly implement the activities under this local study. Most stakeholders felt that it would be more effective for the local study to focus its study on a smaller pilot area rather than the whole of NE Thailand. The lessons derived from this small area could later be applied to other areas that are facing similar challenges. Following this advice from workshop stakeholders, the local study team was open to inputs from stakeholders through the submission of proposals by 31st October 2010. Proposals were required to answer the following questions:
    - Why is the proposed area good or interesting for conducting the study?
    - What are outstanding issues relating to water, food and energy investment in the area?
    - What are the driving forces of change that are important?
    - What are the implications to the Mekong region if different decisions on investment are made?

  After consideration of two proposed areas (i.e. the HSB sub-basin and one sub-district in Surin province) and consultation with the CSIRO, the HSB sub-basin, which is located in the upper Chi river basin of NE Thailand, was chosen as the focus area of the NE Thailand Futures local study.

  Following is brief explanation made by the Chi river basin working group (5T of the MRC) in supporting the selection of the HSB sub-basin:
    - Its GIS database is available for further use.
    - It is a pilot area for the application of the MRC Decision Support Framework (DSF), which requires similar types of data. The working group in this area would like to compare the simulation results of the DSF with other models, e.g. WEAP, that would be developed under the NE Thailand Futures local study.

- There is an on-going Thai-German collaboration project on the sustainable use of surface and ground water, where the issue of concern is related to food, energy crop and land use interaction as well.
- In the area, there are already existing working groups and networks that are dealing with water resources, as well as academic institutes participating in international collaborations e.g. the Thai-German and MRC projects. The private sector, such as the Central Group, is also playing an active role in promoting safe food crops (e.g. chemical-free vegetables). Since a large area in HSB is used for growing energy crops e.g. sugarcane and cassava, the local study should try to carry out research and support development in line with NE Thailand regional policies.
- HSB has been facing problems of water scarcity for domestic and agricultural use, land-use change, deforestation, and poor water resources management, which seem to be typical problems in the Kong-Chi-Mun river basin and Mekong region. Thus, it can be considered a pilot study area to seek long-term solution for other areas.
- It is located in an area to which politicians and governmental agencies pay much attention. There is therefore a high chance that future development plans obtained from the study would be implemented in practice.
- In terms of Mekong regional implications, the HSB sub-basin is located in area area that would benefit from the potential water diversion project from Nam Ngum dam in Laos to Thailand (i.e. through Huai Mong in Nong Khai → Huai Luang in Udon Thani → Ubonrat dam in Khon Kaen → Lam Pao dam in Kalasin → and finally to irrigation areas including the area in HSB. The total water storage capacity of Lam Pao dam has recently been increased for this purpose). So, the decision of growing crops in the area (and thus changing water demand) might have significant implications to the development project in Laos as well.

- **Informal working group meeting on 20th December 2010:** There were around 24 representatives from the Kong-Chi-Mun RBCs, technical working group of the Kong-Chi-Mun RBCs, and concerned regional governmental offices participated in the meeting. The meeting aimed to discuss (1) the formal establishment of the working group for the NE Thailand Futures local study in HSB; (2) the participation and assignments of the working group members; (3) finalisation of the work plan and duration for the local study; and (4) data collection (e.g. data required, the agencies that own data, requesting procedures and additional primary data to be collected).

  It was agreed for the local study to move forward with scenario building exercises using qualitative scenario analysis and quantitative modelling in the study area, HSB river basin. The NE Thailand Futures working group consisting of 27 members representing concerned agencies was officially established in January 2011 by the Chi RBCs, to contribute to the local study for the entire duration of the study, ending in June 2012.

- **1st Scenario Building Workshop during 20-21 January 2011:** Those who participated in this workshop included 45 representatives from the NE Thailand Futures local study working group, the HSB sub-basin working group, representatives from the Kong-Chi-Mun RBCs, and concerned governmental offices and leaders of local communities in HSB. They had considerable knowledge of the history, existing situation and challenges, potential development pathway as well as possible policy response to the challenges within and from outside of the study area. The objectives of this workshop were (1) to develop common understanding of the scenario building exercise and process for the local study in the HSB river basin; (2) to jointly explore the key drivers of change to development in the HSB river basin; (3) to initially define the scenarios, construct the narratives and explore possible policy responses in the HSB river basin to help start qualitative and quantitative analysis work; and (4) to consult with concerned stakeholders, including representatives of NGOs in HSB, on research methodology in the HSB river basin. During the workshop, the local study team and the workshop participants had a chance to visit to the study site to meet and discuss with a few leaders of local communities and farmers on their livelihoods and the current challenges they were facing.

The results from this workshop were an identification of key drivers that are important for the development in HSB (i.e. public participation in the decision-making process, energy demand, profit from cash crops e.g. rice, sugarcane, cassava, rubber and organic vegetables, water management/competition, agricultural land holding) and a construction of four narratives on the future of HSB.

Figure 2: Active participants gathered to explore the future of HSB in the first scenario building workshop, 20-21 January 2011

- **2nd Scenario Building Workshop during 2-3 June 2011:** Participants in this workshop included 60 representatives from the NE Thailand Futures local study working group, the HSB sub-basin working group, representatives from the Kong-Chi-Mun RBCs, and concerned governmental offices and leaders of local communities in HSB. The purpose of this scenario building workshop was to invite participants to revisit first-draft scenarios, which were prepared during the workshop on 20-21 January 2011, to improve the clarity and practicality of the visions and narratives. Participants were able to enrich the draft scenarios in several ways. For example, they could add more imaginative detail about what would happen to key drivers over time; they could also draw on elements from the yet-to-be-used original joint scenario framework. Particularly, they were invited to review the dynamics of stories emerging from the five other settings of the project (Cambodia, Vietnam, Regional, Yunnan, Laos), and provide responses and suggestions to initial findings from the field survey (i.e. household surveys and focus group discussions) and modelling work (i.e. WEAP).

  The two scenario building workshops produced a set of realistic 'visions' for the HSB area, expressed as verbal images and storylines that described an ideal future. The stories produced in the first workshop contained both desirable and undesirable events. The desired events were positive elements of the vision. The visions were realistic to the extent that they were embedded in more complex narratives of change produced by the participants. The outputs of this second workshop are four stories of the future of HSB, which can be found in Annex 1.

Figure 3: The stakeholders producing a set of realistic visions of the HSB area in the second scenario building workshop, 2-3 June 2011

- **3rd Local Study Workshop during 19-20 January 2012:** This workshop was the third among five workshops organised under the NE Thailand Futures local study, and entered a new phase in the workshop series after the two scenario building workshops. In this workshop, the hydrological and livelihood related research results from the NE Thailand Futures local study were presented. The local study team invited workshop participants to discuss the validity of the results and potential policy implications, which would help improve the local study work for the HSB river basin in the future. Participating in this workshop were around 30 representatives from the NE Thailand Futures local study working group, the HSB sub-basin working group, representatives from the Kong-Chi-Mun RBCs and leaders of local communities in HSB.

Figure 4: The workshop participants discussed the validity of the research results and potential policy implications, 19-20 January 2012

- **4th Local Study Workshop during 24-25 May 2012:** This workshop was the fourth among five workshops to be organised under the NE Thailand Futures local study. The draft final results from the integration of hydrological and livelihood analysis and modelling (considering the changes in cropping, climate, water, society, economy, environment and household livelihoods) from the NE Thailand Futures local study, and some progress work of the Mekong Regional Study, were presented. As in the 3rd workshop, the participants discussed the validity of the results and potential policy implications that helped the study team significantly in the finalization of our study as presented in this report. More than 50 representatives from the NE Thailand Futures local study working group, the HSB sub-basin working group, Kong-Chi-Mun RBCs, leaders of local communities in HSB, the private sector, and the Bank of Thailand, actively participated in this workshop.





Figure 5: More than 50 representatives from various stakeholders actively discussed the research results of the NE Thailand Futures local study and Mekong regional study as well as potential policy implications, 24-25 May 2012

2. Primary data collection through livelihoods survey

The local study team in collaboration with Khon Kaen University faculty members and students conducted field work with the aim of investigating the current situation, problems, future trends, and stakeholder opinions relating to the livelihoods of people in the HSB sub-basin. The first method of data collection was to interview representatives of 400 households in the study area by questionnaire. The second method used was focus group discussions among community representatives and related key informants. Data collection held during April to May 2011 had very good participation from the communities and working group.

More information about the field work and its findings can be found in Chapter 3.

3. Secondary data collection

The local study team members collected various types of secondary data, e.g. hydrology, groundwater, land use, population, cropping, development policies and plans on the river basin, province and district levels, from concerned line agencies e.g. DWR, TMD, DGR, RID, TAOs, Municipalities, Community Development Offices, Provincial Office of LDD, NESDB, SEA START, etc.

4. Model application for the research study

Water Evaluation and Planning System (WEAP) and Bayesian Belief Networks (BBN), two mathematical models, were applied in this local study.

- WEAP has been developed to help manage water resources in an integrated way by its analysis of water supply, water demand, water allocation, water use for the agriculture and hydrological analysis. The study completed a simulation of all scenarios and presented the findings to stakeholders in the 4th local study workshop held in late May 2012. Feedback from workshop participants on ways to improve WEAP simulations served as guidance for the local study team in refining the model and finalise model simulation results. More detailed information can be found in Chapter 4.

- BBN is dependent on fuzzy logic. It can analyse changes in livelihoods using the Sustainable Livelihood Framework combined with data primarily collected from field work, all four qualitative stories of future HSB development, and the comments/opinions from individual and organizational experts in improving the model set up and assumptions. Detailed final results on livelihoods analysis and modelling using BBN can be found in Chapter 5.

In addition to above two models, the local study team started exploring groundwater modelling (MODFLOW) that might be useful in improving understanding of groundwater resources (e.g. availability, potential use). This was in response to the strong need for such understanding expressed by local study stakeholders and as observed from our discussion with the leaders of local communities. Given that the study had a limited timeline and resources, groundwater modelling was considered an additional component, the further development of which the local study team would explore beyond the study time span and scope.

5. Technical capacity building activities

From early on in the local study's implementation, key stakeholders strongly suggested including relevant capacity-building activities for working group members and RBCs, in order to increase the sustainability of application of tools from the study, even after the completion of the study.

This was a considerable challenge to the study team as a series of capacity building activities in form of formal (class) trainings would not be allowed given the constraint in available budget and time for the local study. To accommodate this request for the RBCs, the local study team members, especially Dr. Yanyong Inmuong of KKU and Dr. Eric Kemp-Benedict of SEI, put great effort in successfully raising funds from the Fulbright scholarship program to cover the direct costs of Dr. Kemp-Benedict, who had spent a month time in 2011 in Khon Kaen to conduct trainings for the working group members and RBCs. In conclusion, the local study team successfully conducted the following activities to support the capacity building of the RBCs and other concerned parties who have an interest in the tools.

- Training workshop on the application of WEAP and BBN on 22 January 2011 for the HSB working group members
- Training workshop on GIS application and short script writing for WEAP and BBN during 18-20 May 2011 for the HSB working group members.
- Training workshop on the application of WEAP and BBN for the Chi RBCs during 24-25 May 2011
- Final training workshop to hand over data collected and models developed under the local study to the HSB working group members, Chi RBCs and KKU on 25th Oct 2012

CHAPTER 3 Livelihoods Survey

Authors: Uraiwan Inmuong, Graham Eagleton, Phatcharee Srikuta, Angela Bush, Chayanis Krittasudthacheewa

The livelihoods survey of HSB River Basin was part of the "NE Thailand Futures Local Study": a sub-component of the "Exploring Mekong Region Futures Project". The household survey was conducted with the aim of finding out the current situation, problems, future trends, and stakeholder opinions relating to the river basin.

Following the results from the 1st scenario building workshop of the present local study, the key drivers influencing the development in HSB were identified by workshop participants who had considerable knowledge of the history, existing situation and challenges, and potential development pathway, and were used to design the questionnaire of this livelihoods survey.

Issues investigated concerned household incomes, livelihoods, ideas regarding future changes in the water-food-energy nexus, and people's participation in decision-making. The household survey data provided information that might be of use in decision-making about the water-food-energy nexus in Isaan. Furthermore, it can provide greater understanding for stakeholders regarding interactions between the various resource-use sectors which have been changing under the influence of climate change, altering land-use trends, and the expansion of urbanisation.

The first method of data collection was to interview representatives of 400 households in the study area by questionnaire (from a total of 21,129 households) in 20 selected villages (locations of sampled villages shown in Figure 6). The second method used was focus group discussions among community representatives, and related key informants. Data collection held during April to May 2011 had very good participation from the communities and working group.

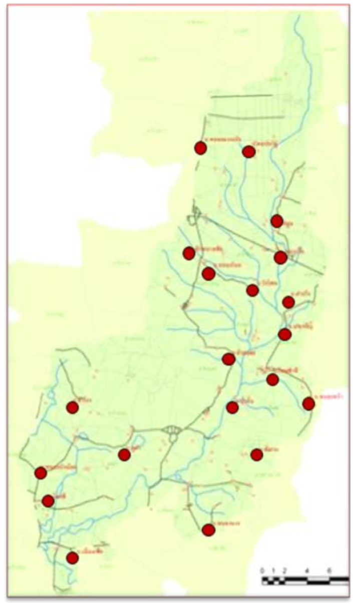

Figure 6: sampled villages in 8 districts of 3 provinces

A summary of results from the household survey is detailed below:

1 A majority of the household representatives graduated from primary school. Their main livelihood pursuit is related to agriculture and supplementary jobs are provided through wage labour, livestock production, or trade. Households have an average monthly income of 9,905 Baht per month, lower than the average household income for NE Thailand; most households in the survey area have debt. The sources of loans are mainly agricultural and cooperative banks and village revolving fund schemes, and the main reasons for debt are household expenditure and agricultural investment.

2 Most households have access to public infrastructure such as roads, electricity, water taps, and mobile phone services. They also possess facilities and assets such as a TV, refrigerator, DVD player, washing machine, car and motorcycle. Some households have agricultural and livestock equipment and machinery, e.g. water pump, water spraying equipment, pushcart, tractor, and/or milling machine.

3 A majority of households own their own land and hold title as Chanote (or deed). Most possess between 2 and 10 rai of land; the land is used for food crops e.g. rice, sugarcane and cassava. Most of these land holdings have no irrigation canals, so farmers have to rely on rainwater. Households with access to irrigation mainly use their lands to grow out-of-season rice. There has been a rapid increase in such irrigated areas in the dry season in recent years. This has led to problems of water competition among water users for out-of-season rice, and to farmer recommendation for more effective water resource management in the river basin to prevent serious problems in the future.

4 There is a water crisis in non-irrigated areas, arising from climate variability (as perceived by most questionnaire respondents and key informants), with drought occurring more frequently than in the past and water sources drying up. This has resulted in insufficient water supply for domestic and agricultural production in the dry season. To deal with this problem, some farmers have switched to crops that require less water.

5 For a majority of farmers, decisions relating to crop type and agricultural systems are determined by market price. High prices for a particular crop product tend to increase the growing area of that crop e.g. sugarcane, cassava and rubber. In principle, the area of food crops tends to decrease while the area of cash crops tends to increase in response to higher market prices of cash crops. However, the majority of the questionnaire respondents believe that switching from growing food crops to growing energy crops would not occur to a significant extent in the long-term future. (Diverse opinions on this finding were widely expressed by the 3rd local study workshop participants, in which many participants believe that the change will be remarkable given the market price is predominantly driven the decision of farmers).

6 Some household representatives who are of working age or have higher levels of education are likely to migrate to work in industrial areas or as wage labourers. Some of them migrate to work permanently, and some migrate temporarily during the non-growing season. Currently, agricultural labour still comes from the same community – and is not yet imported from neighbouring countries – but the cost of local labour has increased because of the lower availability of local labour compared to in the past.

7 The main factor that has negatively affected agricultural production and income is high input prices e.g. of fertilizers, agricultural chemicals, labour cost and oil. Even when agricultural product prices increase compared to the past, the profit is not good enough to cover all household expenses, and household members have had to shift to non-agricultural jobs.

8 The middle-man is the means of market access for a majority of households; access to markets has been increasing compared to the past because agricultural factories have entered the region. Household representatives said that this region will gain more access to export markets arising from development projects with foreign competitors in the near future. They recommend that the government encourage farmers to improve the quality of products to meet international standards and support a reduction in input prices e.g. of fertilizer, oil and energy.

9 Results from the focus group discussions suggested that there has not been much promotion for energy production, but results from the household survey indicate that there has been an expansion in bio-fuel development in this area from both government and private firms. Also, the energy demand in this region is increasing in both agriculture and household consumption as a result of technology development in household facilities, agricultural machinery and fuel use. Household representatives would like to see more earnest support for renewable energy. In the past, the renewable energy policy has lacked the continuity required for successful implementation.

10 People's participation in decision-making in development projects has been increasing compared to the past, but is still not effective or adequate. Villagers have needed to earn an income first, resulting in less engagement with development projects at the community level. Because of the lack of continuous opportunities for villagers to participate in such development projects, household representatives recommend that local authority agencies be allocated more authority to participate effectively in project decision-making processes. The household representatives believe that in the future, people in the community will become more engaged in development projects, leading to problem-solving based on local needs.

These results from the survey of household representatives and community key informants from HSB river basin form part of the socio-economic data, which would be useful for water, food and energy planning. However, this data should be considered along with other data, such as that from another household survey in the HSB river basin (but at different sampled villages) led by the CSIRO; the investigations of environmental resource management, government agricultural promotion, and hydrology; as well as the "Isaan Futures" scenario developed in the project scenario building workshops, in order to project a clearer picture of possible futures for use in future development of this region.

Figure 7: Household survey and focus group discussion conducted during April – May 2011

CHAPTER 4 Hydrological Analysis and Modelling Using WEAP

Authors: Orn-uma Polpanich, Angela Bush, Chayanis Krittasudthacheewa, Eric Kemp-Benedict

1. Introduction

Some major social, economic and physical pressures and issues facing the people of NE Thailand today include: 1) a trend of emigration of locals for better wages and an anticipated trend of immigration of foreign nationals for labouring jobs; 2) growth of the industrial sector with associated increase in factory employment and urban development; 3) pushes for decentralization of power and limitations on people's participation in policy making; 4) changes in the energy sector, including demand, price and source of energy; 5) changes in agricultural profit, including product prices driving land use change and increases in input costs; 6) impacts from climate change and increased water stress, including competition for water between and within sectors; and 7) changes in land ownership and holding size. This chapter describes the use of the Water Evaluation and Planning system (WEAP) to model and investigate scenarios of future water resource development in HSB in order to explore the potential impacts of some of these drivers. Here, we focus on three different changes: climate, irrigation and land use, whereas livelihoods changes are addressed in Chapter 5.

2. Catchment characteristics

The study area, Huai Sai Bat sub-basin (HSB), is one of twenty sub-catchments areas existing in the Chi River Basin and is located in Northeast Thailand, covering an area of approximately 669.71 km^2, accounting for about 1.5% of the Chi River Basin. The catchment spans 10 districts in 3 provinces, namely, Khon Kaen, Kalasin and Mahasarakham provinces. HSB is the major river in the sub-basin and meanders from the north to the south until it reaches the Pong River at Kluay Chueak reservoir at 150 mean sea levels (MSL). The main land use types in the HSB catchment are: agriculture (72.35% of total catchment area), forest (15.74%), urban areas (3.56%), water bodies (1.35%) and others such as shrubs, wetlands and grass (7%). The main agricultural crops grown are rice, sugarcane, cassava and corn.

The climate conditions of the catchment are characterized by strong southwesterly and northeasterly monsoons and depressions, defining three seasons of the area: hot, rainy and cold. The annual average precipitation in HSB is approximately 1,030 mm, with the rainfall peak occurring mainly in September (average monthly total 196 mm). The monthly average temperature varies between 22.7 °C in the cool season (December) and 29.6 °C in the hot, dry season (April).

Different water users (i.e. agriculture, domestic, irrigated agriculture, industrial forest) are present in the catchment. A big share of the agricultural land is allocated to rice production which requires a high quantity of water; water resources are vital in the development of Thailand (Naivinit and

Trebuil, 2006), and of the NE region. Although the region has an annual average rainfall comparable to other parts of the country, there is severe shortage of water during December to May and the rainfall pattern is erratic (Naivinit and Trebuil, 2006). Moreover, unproductive marginal soils often limit crop yields in NE Thailand (Panchaban, 1989).

There are several future plans to be established in the HSB sub-basin: the Kong-Loei-Chi-Mun project, water diversion from Nam Ngum River, and the Water grid (Molle and Floch, 2008). In regard to these mega-irrigation projects, being able to assess the ability of the catchment to satisfy its future water demand is essential for good planning and decision-making in the future.

The WEAP model is set up to accept interrelations between physical impact , climate change, and socioeconomic development. These features are being used to estimate potential drivers of ecosystem change from changes in land use, climate and water in an application developed for the HSB, covering an area of three provinces: Kalasin, Khon Kaen and Mahasarakham, Thailand. It was used to construct a water resource database and an associated advanced hydrological planning model that represents the entire basin. It integrates both hydrology and water resource planning in the basin and uses to evaluate the hydrological feasibility of a suite of scenarios for improving the management of the limited water available in the basin.

In this report, the new version of WEAP is applied to several, at times hypothetical, water resources planning issues in the HSB. Because the scenarios are illustrative, they do not fully represent the conditions or issues in the entire NE Thailand. Some of data values are based upon expert judgment. The scenarios do, however, provide guidance on the use of the WEAP model.

3. Methodology

4.1 WEAP as a hydrological modelling tool

WEAP is a Windows-based decision support system for integrated water resource management and policy analysis (http://www.weap21.org/). It is a model-building tool, used to create simulations of water demand, supply, runoff, evapotranspiration, infiltration, crop water requirements, groundwater and surface storage and reservoir operations, all under scenarios of varying policy, hydrology, climate, land use, technology and socio-economic factors. WEAP provides a seamless integration of both the physical hydrology of the region and water management infrastructure that governs the allocation of available water resources to meet different water needs (Stockholm Environment Institute, 2011). Given the anticipated higher water demand in NE Thailand and possibly higher scarcity in the future, WEAP is an appropriate tool for exploring optimization options for the valuable water resources of the HSB catchment.

As a rainfall-runoff model, WEAP has several options for calculation of streamflow and water balances. In this instance, a two-bucket model, the FAO rainfall runoff and irrigation demand method (1998), was chosen so that both soil water and groundwater could be simulated. Figure 8 shows how water movement between two layers of the catchment are modelled, and also shows some important inputs (e.g. water use and climate data) and outputs (e.g. streamflow). By changing the data sources of inputs, we altered the conditions and created several scenarios for the HSB catchment.

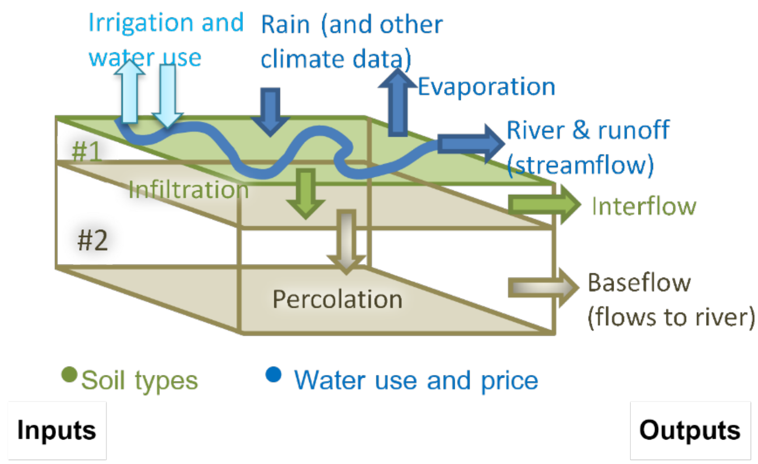

Figure 8: Schematic diagram of two-bucket model used in WEAP with some inputs and outputs

4.2 Model setup and scenarios

The total land area of HSB is 669.71 km^2 (Department of Water Resources Region 4, 2012), which was divided into 8 sub-catchments for the WEAP model setup, each with an unnamed, numbered stream tributary to the HSB mainstream (with the exception of the headwater sub-catchment which simply drains to the HSB mainstream; Figure 9 and Table 1).

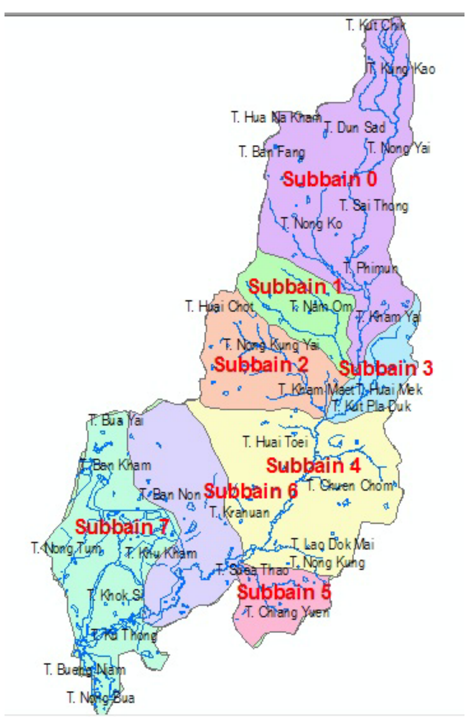

Figure 9: Map showing the configuration of the WEAP model to simulate flow within eight sub-basins (C00 to C07) of HSB basin used for the model calibration.

Table 1: Tambon (sub-district) coverage area in eight sub-catchments

Sub-catchment	Tambon coverage
0, C00	Kut Chik, Kung Kao, Hua Na Kham, Dun Sad, Ban Fang, Nong Yai, Sai Thong, Nong Ko, Phimun and Kham Yai
1, C01	Nam Om
2, C02	Huai Chot, Nong Kung Yai, Kham Maet
3, C03	Huai Mek and Kut Pla Duk
4, C04	Huai Toei, Chuen Chom, Lao Dok Mai Kranuan and Nong Kung
5, C05	Chiang Yuen
6, C06	Ban Non, Suea Thao
7, C07	Bua Yai, Ban Kham, Nong Tum, Khu Kham, Khok Si, Ku Thong, Bueng Niam and Nong Bua

In WEAP, the typical scenario modelling pro forma consists of three components: a current account year, which is chosen to serve as the base year of the model; a reference scenario, that is established from the current accounts year to simulate a likely evolution of the system without intervention; and then several "what-if" scenarios, which are alterations of the reference scenario. A set of scenarios (Table 2) was developed and described as Current trends, Land use change, Climate change, Water resource development, Calibration, and Income change, with the aim of exploring the important drivers of change and also the common themes of stories devised by participants in the scenario building workshops of the early stages of the project. As a comparison for all the potential changes in scenarios, the baseline scenario (A) was created from the current account year (1980) and the reference scenario (running until 2030), and represents a continuation of current conditions, without much change.

Table 2: The names and details of the WEAP scenarios developed

Basic scenario	**Code**	**Description**
Baseline (A)	A*	Baseline scenario: land use, water use and irrigation which represents a continuation of current conditions, without much change and climate is based on historical data
Type of Scenario	**Code**	**Description of alteration made to baseline scenario**
Land Use Change (B)**	B1a*	All rice land is converted to sugarcane, assuming of extreme change
	B1b*	Only rice land suitable to sugarcane is converted to sugarcane
	B2*	Change un-irrigated crop areas to irrigated crops
	S1a	Integrated farming vs. energy crops (rice decreases)
	S1b	Changes in land use in line with trends in crop price
	S2	Reforestation of upland areas
Climate Change (C)	C2a*	Climate change: high GHG (ECHAM4 A2)
	C2b*	Climate change: lower GHG (ECHAM4 B2)
Water Resources Development (D)	D1*	100% land irrigated: diversion from the Mekong for Kong-Loei-Chi-Mun project
	D2*	Irrigation changes/Dams/Reservoirs/Storage (a combination of these)
Calibration (E)	E1	Calibration scenario: with gauge E67 scaled for the entire HSB
	E2	Calibration scenario: with a different gauge and/or a different location in HSB
Income change (I)	I1	Same Equality (constant Gini) with Isaan growth linked to income growth
	I2	More equality (decreasing Gini)
	I3	Less equality (increasing Gini)

* Scenarios discussed in this chapter
** Any scenario labelled with an "S" is derived from common themes of scenario building stories.
Note: Definitions of A2 and B2 were based on the Third Assessment Report of IPCC (2000)[1] and SEA START (2010)[2]. The two scenarios were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions, and their evolution during the 21st century for large world regions, and globally.

The scenarios discussed in this chapter relate to changes in land use (specifically B1a, B1b and B2), climate change (C2a and C2b) and the development of water resource infrastructure (D1 and D2).

[1] The IPCC published a new set of scenarios in 2000 for use in the Third Assessment Report (Special Report on Emissions Scenarios – SRES). Online: http://sedac.ciesin.columbia.edu/ddc/sres/index.html

[2] The Southeast Asia START Regional Center published the summary of climate change in Thailand on January 15, 2010. Online: http://startcc.iwlearn.org/doc/Doc_eng_15.pdf

Scenario D1 (100% land irrigated from large diversion schemes from the Mekong to the Chi River Basin) considers the proposed mega-irrigation projects in the Lower Mekong Basin (LMB) countries that could have profound and wide-ranging socio-economic, irrigation development and environmental affects in all LMB countries, and even in Northeast Thailand. Considering this, scenario D1 is built from the proposed development of transboundary water diversion from Laos' Nam Ngum river to Huai Luang river and storage at the Lam Pao dam in the northeast Thailand province of Udon Thani, worth some 76.6 billion baht (2.3 billion dollars). In this development plan, the diverted water will be also imported to the HSB sub-basin. It is estimated that the total proposed irrigation area is about 0.9 million ha from the entire project and estimated water demand is approximately 13,750 million cubic metres (MCM), which will account for 430 m^3/s.[3] This scenario was chosen in this study because it will be directing future national and local development. The scheme has offered vast economic opportunities to reduce poverty and ensure that the river flow meets future agricultural needs in the Lower Mekong countries. The project team saw that past assessments projected benefits for local communities in this scenario, and wanted to investigate whether such a large-scale water management scheme is really needed, and what implications and opportunities could be seen.

Our investigation in the water resource development scenario (D) also included D2 – irrigation changes/dams/reservoirs/storage. This scenario was explored because DWR (2006) drew a plan to develop medium and small scale projects in the HSB sub-basin for multiple purposes: agriculture, industrial and residential use. DWR has also estimated that the future water demand of all activities in the HSB catchment will increase from 28.87 MCM in 2002 to 35.50 MCM per annum in 2022, an increase of 6.63 MCM per year. To resolve water scarcity in the entire HSB catchment, there is a need to increasingly build water storage areas throughout the areas, considering only available water resources in the catchment and the absence of additional water from external sources.

4.3 Data collection and preparation

The details of each scenario of the WEAP model are explained below as the input data is described. Unless stated otherwise, inputs for all scenarios are the same as the baseline scenario; also, unless time variation is indicated, inputs for all subsequent years are based on the current accounts year.

4.3.1 Domestic water use data

The data on water consumption in the HSB sub-basin is provided by an estimation of the number of domestic water users, which gave the total domestic water use for 23 sub-districts in the entire catchment. Population was scaled down for each sub-district according to the percentage of its land use inside the HSB catchment. If the sub-district area in the HSB catchment was less than 10% of total Tambon area, it was excluded in the estimated domestic water use.

[3] Mekong River Commission conducted the strategic environment assessment (SEA) of proposed hydropower developments on the mainstream Mekong River in 2009. Online: http://www.mrcmekong.org/assets/Publications/Consultations/SEA-Hydropower/12.Thailand-Baseline-Assessment-Perspective28Jan.pdf

Data on water use per capita per for 30 years (1980 to 2010) was obtained from the Population Information Centre (College of Population Studies, Chulalongkorn University, 2008). To generate population data for the years 2011 to 2030 of the baseline scenario, 2010 values were extrapolated at a growth rate of 0.2% per year (Wapattanawong and Prasartkul, 2005; National Economic and Social Development Board, 2010). The projected population is used to estimate the per-capita domestic water use rate, which is estimated to be approximately 50 m^3/yr (Department of Water Resources, 2006), but was set higher, at 62 m^3/yr (170 L/day). The rate of consumption of domestic water was set at 15%, meaning that 85% of water used domestically would return to the HSB catchment.

4.3.2 Industrial water use data

Three industrial water use nodes exist in the baseline scenario, centred on the three industry locations in the HSB sub-basin. The first industrial water use node is Dun Sad, currently using 387,000 million m^3 per year. The second node is Kranuan, using 161,000 million m^3 per year. The third node is Khok Si, using 1,032,000 million m^3 per year. An estimate of future industrial water use for the three nodes by 2022 from the DWR (2006) for the HSB catchment is 1.315, 3.946, and 3.508 MCM per year, respectively. In the HSB basin, these demands are met largely through inter-basin transfers from additional irrigation (see 4.3.4, Other water supply). This industrial use is prioritised second to agricultural use, with groundwater as the first preferred water source, and surface water the second.

4.3.3 Agricultural water use data

Crop coefficient is the key variable controlling agricultural water demand in the baseline scenario. Crop coefficients (Kc) are relative measures of crop water requirement. The values used in this study were based on assessment of published values for different land use categories (Allen *et al.*, 1998; Watanabe *et al.*, 2004). The crop coefficients determine the rate and timing (monthly) of crop water use; however, crop areas are determined by land use. Overall, monthly Kc values were assigned for ten land cover types, but two sets of Kc values were devised for four of these (rice, cassava, sugarcane, and integrated farming) for both irrigated and rainfed areas (which change according to scenarios). It is assumed that rainfed crops follow a typical growth season, while irrigated crops have two harvests per year, and other land uses (e.g. grassland and woodland) have continued transpiration in the dry season.

4.3.4 Other water supply

There are two additional water use nodes in the model. The first node supplies water to sub-basin 6 (called “C06” hereafter) and the second to C07. In the HSB sub-basin, these two additional irrigation nodes adequately fulfil water need and provide on-demand irrigation for all activities in the two sub-basins all year round.

4.3.5 Crop water requirement

Water use by crops was calculated in WEAP using the FAO Rainfall Runoff Method (soil moisture). Kc values for crops were estimated from literature. Key assumptions in the estimated Kc values were:

1. Irrigated sugarcane: the crop would be planted in October after fallowing, and harvested 15 months later. It would then be rationed 4 times at near maximum productivity, with this process repeated in 6-year cycles. However, in scenarios where the whole catchment was devoted to sugar cane, the system would approach an irrigated system, utilizing available soil moisture with higher fertilizer inputs, than is the case in the current reference situation.
2. Rainfed sugarcane: the crop would be planted in October after fallowing, and harvested 15 months later. It would then be rationed once at a lower level of productivity. The whole cycle would then be repeated i.e. fallow, plant, 1 ratoon.
3. Irrigated rice: High-yielding wet season crop with supplementary irrigation, followed by one month of fallowing, dry season high yielding irrigated crop, and one month of fallowing. This is repeated for six years.
4. Rainfed rice: Normal wet season rainfed crop, followed by a long grassy grazed fallow. This is repeated for six years.
5. Irrigated cassava: This is not a very likely scenario, but we have assumed the following:
    a. Ground preparation, planting in March, a long duration crop with supplementary irrigation harvested 14 months later, and fallowing. The cycle is repeated in three 2-year cycles in 6 years.
    b. Rainfed cassava: the crop would be planted in October, harvested in May, followed by fallowing for a total of six cycles
6. Other vegetation types (i.e. forest, grass, integrated agriculture, etc.) are considered unchanging in the model.
7. Kc values for rice are higher than for sugarcane, but for a shorter period of time. Influence of Kc is directly related to water need. Although Kc values for sugarcane are lower, but for a longer period than for rice and irrigated rice. The total growing periods of rice, irrigated rice and sugarcane are 6 months, 3-4 months and 9-12 months, respectively. Therefore, sugarcane needs more water than rice when considering the total growing period.

In this case the Kc values for the model were averaged over the six years. The modelled Kc values are presented in Figure 10.

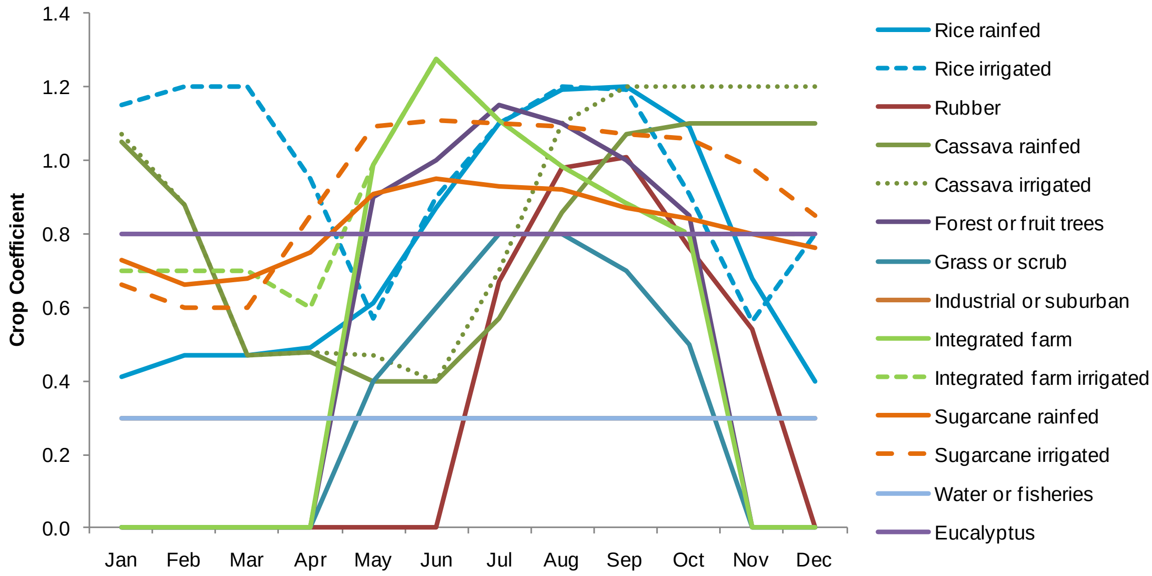

Figure 10: Input crop coefficients (Kc) derived for ten land cover types (four with irrigation options)

4.3.6 Land-use data

Baseline scenario

Land use was an input to WEAP, which influenced rainfall-runoff and consumptive water usage in specific local contexts. This input was adjusted to reflect any new management strategies to protect and reclaim or otherwise modify land use. Quantified land-use cover over the past 30 years was used to create the land-use dataset for each year of the baseline scenario (1980–2010), and the interpolation function of WEAP was used to estimate the future land-use cover (2011-2030). This required data input for several years, after which the WEAP model interpolated the data to define inputs for all other years. Input data used is below.

1) 1980-2007: Land-use data were derived from three province-scale maps of land cover: Khon Kaen and Kalasin (from 2008) and Mahasarakham (2006 data) provided by the Northeast Region Land Development Department (LDD). As province administration boundaries and HSB boundaries do not coincide, it was necessary to combine these data. First, all land cover categories of the LDD data were assessed and regrouped into 14 categories, namely: (1) rainfed rice, (2) rubber plantation, (3) rainfed cassava, (4) forest or fruit trees, (5) grass or scrub, (6) industrial or suburban, (7) integrated farm or mixed crops, (8) rainfed sugarcane, (9) water or fisheries, (10) eucalyptus plantation, (11) irrigated rice, (12) irrigated cassava, (13) irrigated sugarcane, and (14) irrigated mixed farms). Then the reclassified data were merged into a single polygon shapefile using ArcGIS, which was eventually cut into the HSB sub-catchment areas, providing summary land cover data (as percentages of sub-catchments).
2) 2011-2030: a future land use change data set for the next 20 years was derived from the analyses of land suitability and increases in irrigated areas, described in sections 3.3.6.2 and 3.3.6.3

<u>Land-use change scenario: B1b – only rice land suitable for sugarcane is converted</u>
The scenario was assessed because of the rapid expansion of biofuel cultivation together with current renewable energy development in Thailand. Therefore, the crop suitability and land evaluation for HSB catchment used the GIS technologies, in order to assess the land types and classes according to their capacity.

Rice areas suitable to sugarcanes were the prime focus in crop suitability analysis for this scenario. Figure 11 presents the work flow of the land suitability analysis.

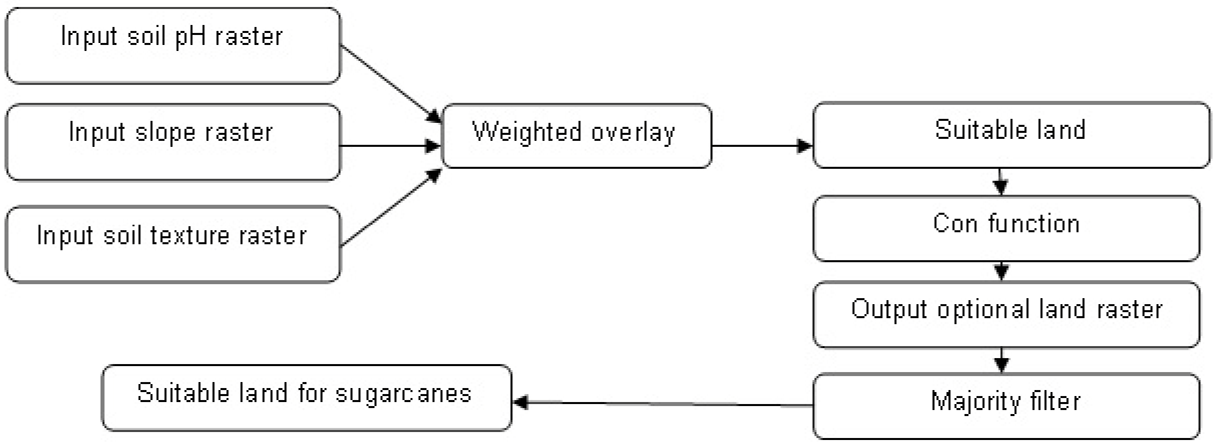

Figure 11: Schematic of the conceptual framework underpinning the study for analysis of land suitability, assigning rice areas suitable to sugarcane

In a number of cases (Mutua, 2012; Paiboonsak and Mongkolsawat, 2007), crop suitability was quantified based on the following factors:

- Soil depth of at least 80 cm, because sugarcane has long life-span and a deep root zone
- Good drainage system in such soils
- Organic matter above 1%
- Soil pH between 5.5 - 7.5
- Annual rainfall distribution greater than 1,500 mm per year
- Slope ranges between 2-20%

The equation used to analyse land suitability was:

Land suitability = RN x NAI x Slope

where RN is annual rainfall distribution in mm; nitrogen, phosphorus, potassium, organic matter and soil pH levels are used in the overlay process to create the spatial layer of NAI (Paiboonsak and Mongkolsawat, 2007). Slope is the percent of slope ranges.

Land-use change scenario: B2 – change non-irrigated crop areas to irrigated crops
In this scenario, areas of anticipated rice farms and other crops are increased in the HSB catchment due to a large expansion of irrigation (Figure 12). Two factors used in the estimate of area increase were (i) areas of crops along the river network in the HSB, and (ii) the fact that those areas increased in width by 500 metres from the streamline.

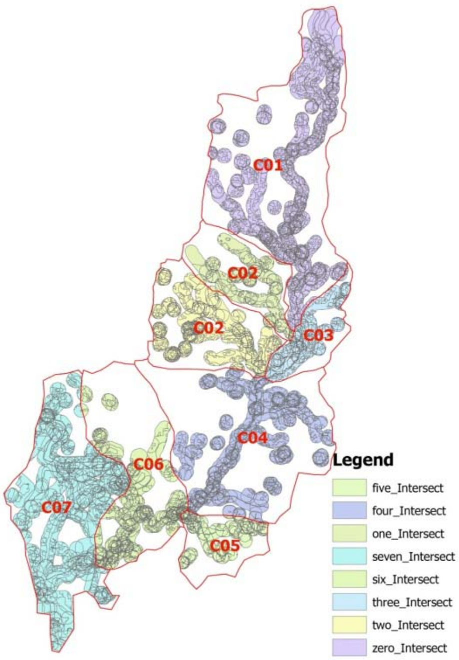

Figure 12: Increase in area of irrigated rice and other crops in the HSB basin under scenario B2

4.3.7 Climate data

The climate parameters required for the model by the FAO rainfall runoff method are: monthly precipitation, average monthly temperature, average monthly wind speed, average monthly relative humidity and average monthly sunshine hours, collected as cloudiness. All these parameters were obtained for the period 1980-2010 from the central division of the Thai Meteorological Department (TMD), and are the basis of the inputs for the baseline scenario. For the climate change scenario, the regional climate modelling results of the Southeast Asia START Regional Centre (http://www.start.or.th) were selected due to their focus on the geographical region of this study and their broad applications in other projects of the GMS.

All scenarios: 1980–2010
The TMD data for the parameters of wind speed, cloudiness, temperature and humidity were available for only five monitoring stations in the region of HSB: the provincial monitoring stations of Udon Thani, Khon Kaen, Mahasarakham, and Kalasin, and a second station in Khon Kaen province, Tha Phra Agromet. These data were obtained in a monthly format and were therefore directly applied to interpolations in GIS. The TMD precipitation data were from 82 monitoring stations in a map region bounded by the northwest coordinate (102.12, 17.72) and southeast coordinate (103.9, 15.48). The precipitation data were obtained in a daily format and were

subsequently processed to obtain monthly totals. All months were checked for missing daily measurements; if one measurement was missing, the data for that month was defined as insufficient. Stations with more than 20% insufficient months were excluded from the analysis (n=49), leaving 33 stations for interpolations. The missing data of the insufficient months of the 33 remaining stations were filled using the monthly average of nearby stations for each specific month/year.

Once complete monthly datasets for all the parameters were produced, the interpolation of station point data was performed in ArcGIS to produce a contoured surface. The interpolation method used was kriging, employing a Gaussian semivariogram and a cell size of 0.05 × 0.05 decimal degrees. Extent of the interpolation was a region bounded by the northwest coordinate (102.5, 17.5) and southeast coordinate (103.7, 16.1). Interpolation by kriging was selected after comparing the results of 12 rainfall interpolations with results from Inverse Distance Weight (IDW) and spline interpolations (36 interpolations in all) for the rainy months (July, August and September) for the especially dry years of 1993 and 1994 and the wet years of 1995 and 1996. From this analysis, it was clear that kriging dealt best with the noise in the data sets and produced contour patterns most similar to a regional rainfall dataset from the Climatic Research Unit (CRU). Due to the lack of spatial variation in the cloudiness data, and some months of the wind speed data, inputs across the study area are single values for those months.

After interpolated surfaces had been created, representative values of each parameters' monthly values were extracted for each of the 8 sub-catchments of the HSB model area (i.e. one value per month per sub-catchment). These data formed the inputs for WEAP for the years 1980 through 2010 for all scenarios.

<u>Baseline scenario: 2011–2030</u>
Randomly generated datasets for rainfall and temperature were produced using the WEAP inputs for 1980 to 2010 as a basis. The process used was: i) the months of all the years from 1980 to 2010 were given systematic numbers such that all Januaries fell within a certain range, etc.; ii) each month of each year in the new data set (2011 to 2030) was allotted a random number, but these numbers where within the 12 ranges, such that the random number for any January between 2011 and 2030 must correspond to a January in the past; iii) the corresponding past data were inserted into the new dataset for the appropriate months according to the random numbers.

<u>Climate change scenario C2a and C2b: 2011–2030</u>
For the climate change scenario C2a, modelled daily data for a hypothetical future 20-year period (2011-2030) were downloaded from SEA START (http://www.start.or.th), for gridpoints at a 0.2 decimal degree spacing, covering a map region bounded by the northwest coordinate (102.4, 17.6) and southeast coordinate (103.8, 16.0). The ECHAM4 version of the model using the A2 greenhouse gas (GHG) scenario was selected in order to represent a reasonable range of climate variation from fairly high GHG emissions, and due to its broad application in other projects of the GMS. This model was also chosen due to its accurate representation of surface features such as topography and coastlines. The regional climate model ECHAM4 is a global circulation model (GCM) which is run on a daily time step at a spatial resolution of 0.22° (about 20x20 km gridcells).

The data from SEA START used were for the parameters of precipitation, temperature and wind speed. The data were originally provided in daily formats and were processed to provide monthly values. Total modelled precipitation and average modelled wind speed were used; however, rather than the monthly average temperature, an average of the modelled minimum and maximum temperatures was used. The SEA START data are derived from a model grid and was provided as point data with a spacing of 0.2 decimal degrees in latitude and longitude. This spacing was wide enough to allow one point to be attributed to each of the eight sub-catchments of the HSB model. A script was written in *Excel* to extract the data from the points that geographically coincided with the HSB sub-catchments.

The two emission scenarios used were the A2 and B2 scenarios:

"**The A2 SRES regional emission scenario** describes a very heterogeneous world with respect to slower and more fragmented technological changes and improvements to per capita income, regionally oriented economic development, and self-reliant nations. It is expected to generate 120,000 CO2 tonnes equivalent per annum of GHG emission and temperature increases to 3.4 deg Celsius. By contrast, **the B2 is a world which the emphasis on local solutions** to economic, social and environmental stability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in A1 and B1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels. This scenario is predicted to generate 40,000 CO2 ton equivalent per annum of GHG and 2.4 deg Celsius increases in temperature" (SEA START, 2010).

Notably, the team did not apply bias-correction in the future climate data downscaled by SEA START due to limited time. Only a statistical test comparison between mean annual rainfall of observed data and project data was applied. However, the result did not show us a substantial gap between those two datasets, so the team decided to use the projected climate data as it was.

4.4 Model calibration

The HSB basin does not have a streamflow gauge station. Therefore, different assumptions for temperature and precipitation, the main climatic drivers in the model, were distributed with height and location. The WEAP model was calibrated using data from gauged basins with similar local condition (e.g. soil characteristics, size, vegetation cover, etc.) located on the upper part of the Chi river basin. Calibration involved changing assumptions about (i) rapid expansion of biofuel crops, and the resulting land-use conversion and water demand; (ii) establishing sugarcane and cassava processing in the HSB; (iii) development of transportation infrastructure; (iv) a large-scale water diversion and management project, diverting water from Kong-Loei-Chi-Mun; (v) improved irrigation schemes, diversion, etc. in the catchment; (vi) changes in climate conditions in the future, resulting in changes in land-use, water resources, etc. The only factor used in the calibration was a reduction factor for the catchment/basin area. Specifically, visual comparisons of the simulated and observed time series and monthly means were used. This is unlikely to be the case in reality, since limits will have been placed on specific basin areas and associated biophysical environments.

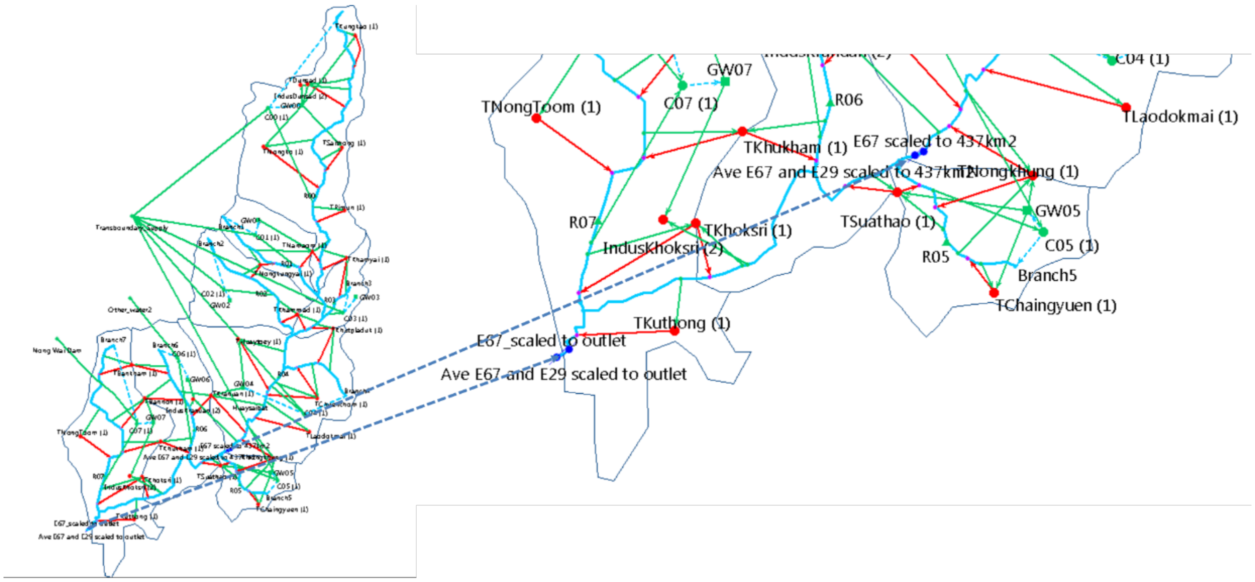

Figure 13: Map showing location of the selected gauged stations that was used in the calibration of the model

The runoff efficiency (volume of runoff per unit area) increases with the decreasing size of the catchment, i.e. the larger the size of the catchment, the longer the peak period of runoff and the smaller the runoff efficiency. Stream gauge stations and reduction factors for runoff estimation at the HSB basin were evaluated (Table 3) using an equation developed by FAO (1988):

$$\text{Reduction factor} = A1 \times Y1 \;/\; A2 \times Y2$$

Where,

A1 and A2 are catchment areas of calibration point in the HSB and the selected stations, respectively.

Y1 and Y2 are the specific runoff yield in litre per second per km^2 of the HSB catchment and selected stations, respectively.

Q discharge at the HSB catchment is the reduction factor multiplied with the Q at the selected station.

Table 3: Statistical computation for the validation period for the HSB basin

Station	Sub-catchment	Catchment area (km²)	Specific runoff yield (l/s/km²)	Reduction factor for CA=677.63 km2	Reduction factor for CA= 476.00 km2	Reduction factor for CA= 437.23 km2
E67	Lamphanchart sub-basin	476.00	15.31	1.12	0.78	0.72
E65	Upper part of Lam Pao sub-basin	2,147.00	10.85	0.35	0.25	0.23
E54	Nam phong sub-basin	1,548.00	12.83	0.41	0.29	0.26
E29	Upper part of Nam Phong sub-basin	949.00	9.92	0.86	0.61	0.56
HSB	HSB	669.71	12	1.00	0.70	0.65

4. Results and discussions

This section presents only the results of the selected scenarios assessed in the study. Four modelled results are (1) model calibration, (2) B1b vs. B2 under the land-use change scenario, (3) C2a and C2b vs. Baseline under the climate change scenario and (4) water resource development (D).

4.1 Model calibration

From modelled result, the calibration increases total flow very little difference. Therefore, we decided to continue with the default parameters, rather than use the calibration values. Figures 14 and 15 present the comparative results of the model calibration.

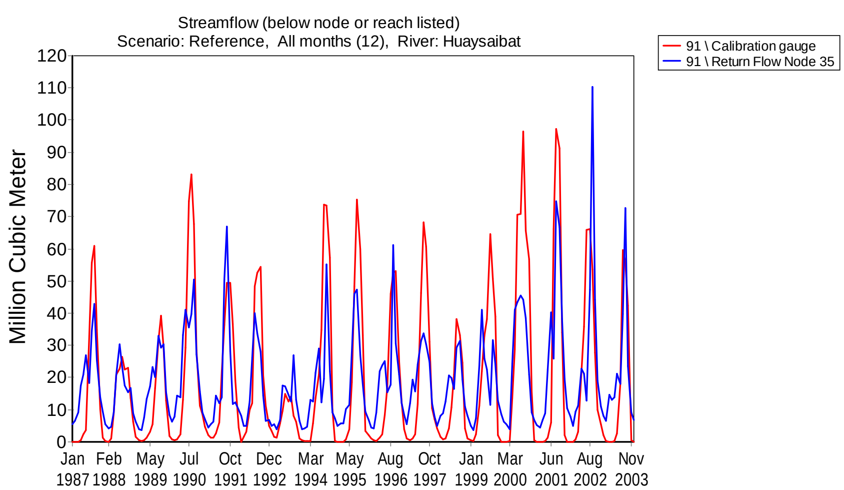

Figure 14: Annual streamflow in the entire HSB catchment before the model calibration

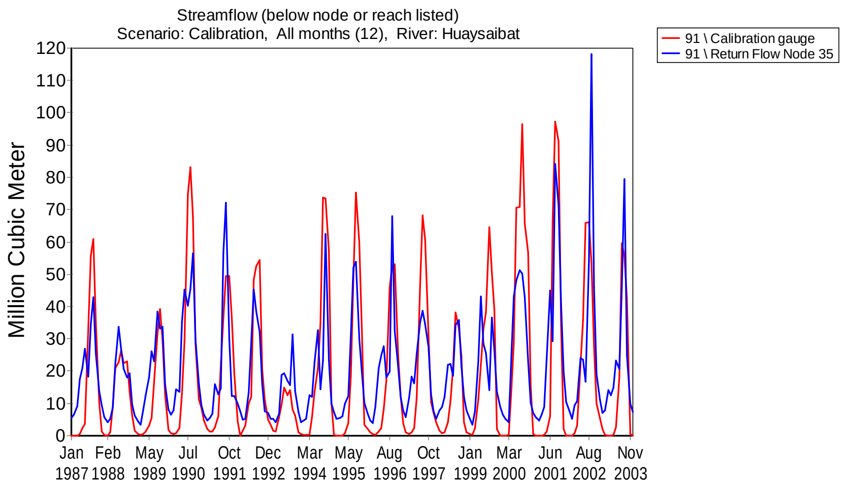

Figure 15: Annual streamflow in the entire HSB catchment after the model calibration

Calibration is performed by comparing observed and modelled monthly streamflows at the outlet of two main sub-catchments (Figure 16). In terms of the quasi-physical parameters, the most relevant areas are those affecting to the ability of the soil to hold and release moisture. Other relevant physical parameters represent soil and vegetation characteristics of the similar sub-catchments. The exceptions would be the Lam Phan Chart (E67) and Upper part of Nam Phong (E29) gauging station, where due to data availability, we have considered 1980-2010 as the calibration and validation periods.

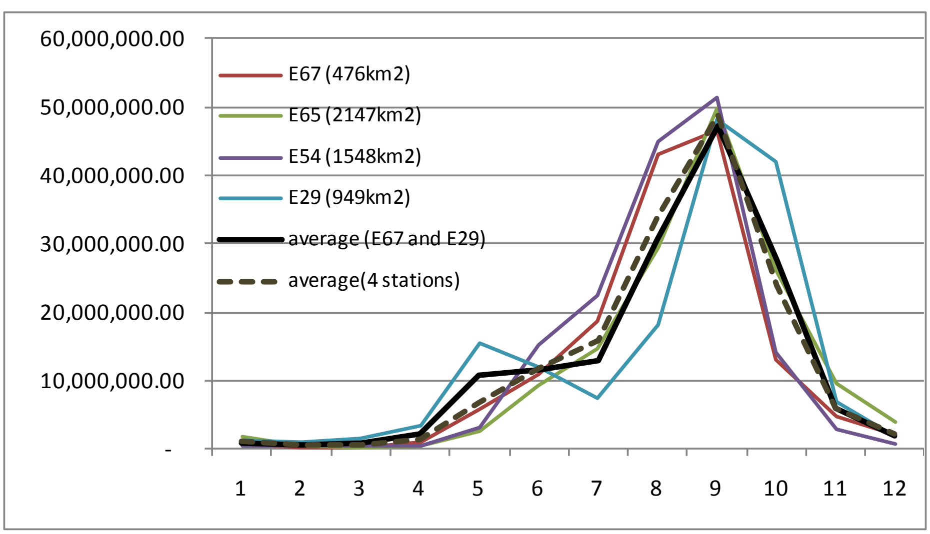

Figure 16: Annual monthly runoff at the outlet of two main sub-catchment in the HSB (m^3**)**, compared with the observed runoff

In this calibration, together with available data, irrigation fraction and groundwater values are not modelled, which could alter streamflow in specific months of the year. In our model irrigated land is held static; however, considering the time lag between the calibration and validation periods, there could be some unrepresented differences. Figure 16 shows the monthly pattern is properly simulated by the model, confirming that the streamflow and runoff process are adequately represented.

5.2 Baseline scenario

5.2.1 Agricultural water use and unmet demand

In the baseline scenario, unmet demand for agricultural water is mainly in the upper midstream areas of the HSB basin (C03 and C02; Figure 17) and is concentrated in the dry season, especially during January-April annually.

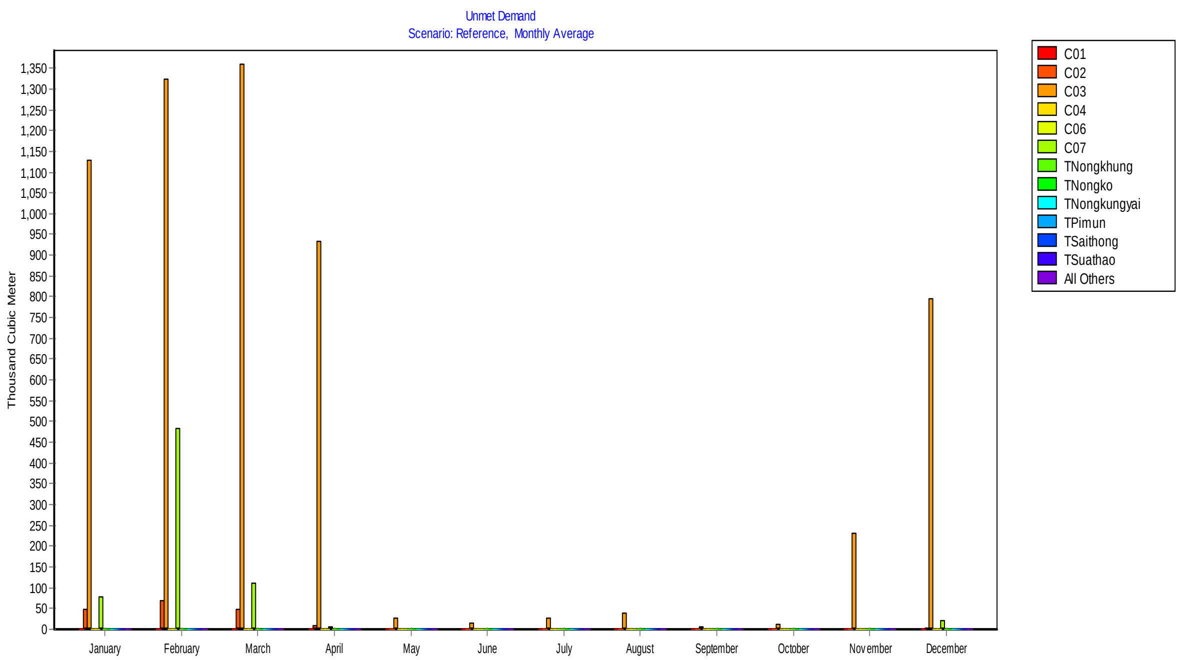

Figure 17: Unmet water demand under the Baseline scenario (A)

Comparing the baseline scenario with the land-use change scenario, the results show that the high concentrated unmet water occurs in the midstream areas of the HSB basin (C03); low to fairly low unmet demands are in C02 in the upper midstream area and downstream area in C07. Figure 18 shows the unmet demand in the entire HSB basin under B1a – 100% rice areas converted to sugar cane.

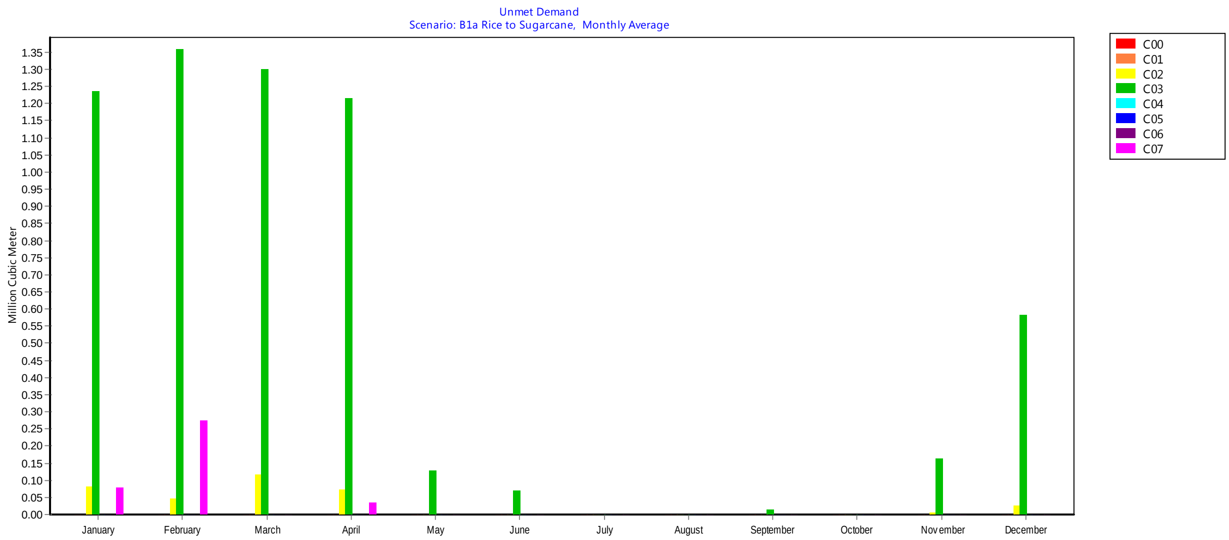

Figure 18: Unsatisfied water demand in the HSB basin under the B1a land use change scenario

The results of the land-use change scenario (B1b) - only rice crop areas that are suitable to change to sugarcane - show that the midstream areas of the HSB basin (C03) will face big challenges with water scarcity in the annual dry period (November – April).

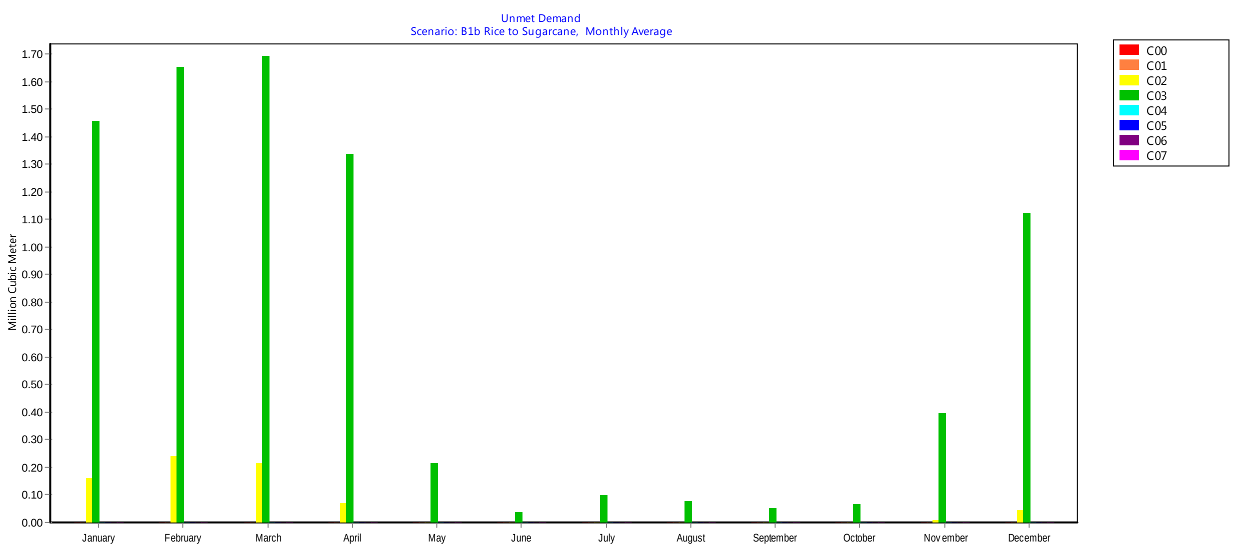

Figure 19: Unsatisfied water demand in the HSB basin under the B1b land use change scenario

If water demand increases in the HSB basin together with large increases in areas of irrigated rice and other crops in the basin, the results modelled show that all sub-basins will face water shortages throughout the year. The largest areas affected by water shortages are modelled at the upstream and midstream areas of the basin (C00, C04, C02 and C01, respectively). Thus the expansion of irrigated areas, which use water resources from within the HSB basin, will result in future water scarcity in the area. Innovative techniques such as rainwater harvesting, increasing water productivity and reusing urban wastewater could be options for maximising the use of available water in agricultural activities.

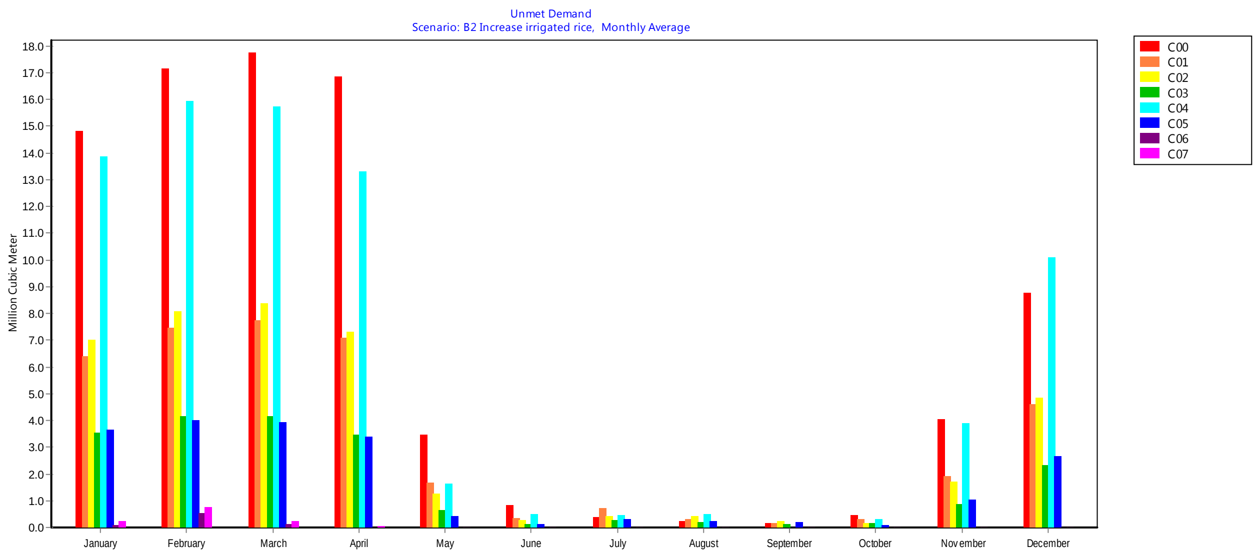

Figure 20: Unsatisfied water demand in the HSB basin under the B2 land use change scenario

The predicted crop water requirements in the HSB basin in the next 20 years (until 2030) is described below.

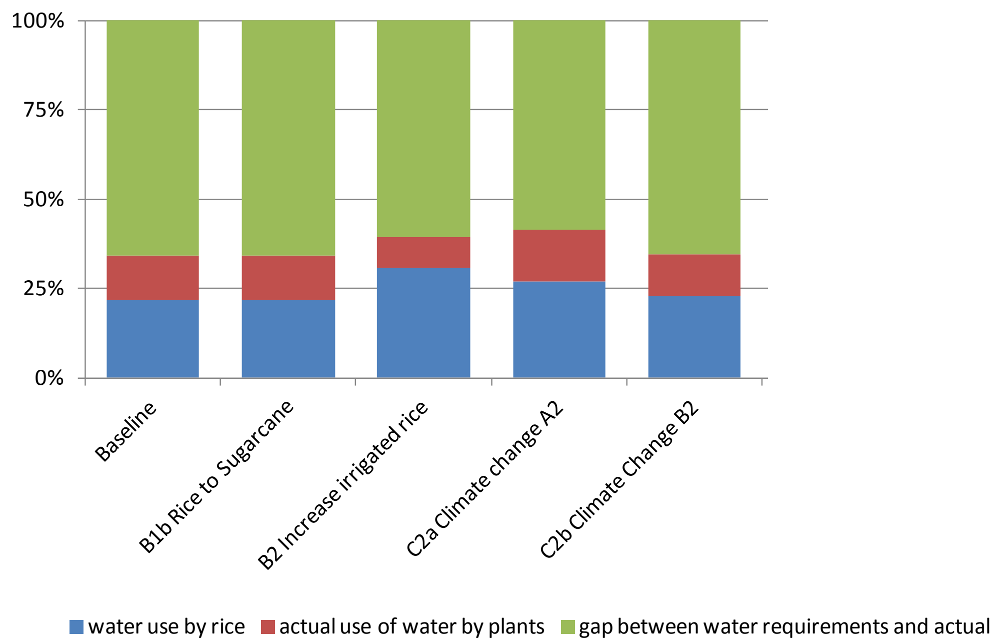

Figure 21: Prediction of water demand in the HSB basin over 20 years (until 2030), under different scenarios

Comparing current water use under the baseline scenario to other scenarios (B1b, B2, C2a, and C2b) indicates that there are great differences of crop water requirement in the HSB basin. When comparing climate change scenario (C2a) and other scenarios, there is little difference between crop water needs. More precisely, in the climate change scenario it illustrates that C2a has little crop water requirement compared to the actual crop water use. Meanwhile, C2b has larger gaps between future and current crop water requirement.

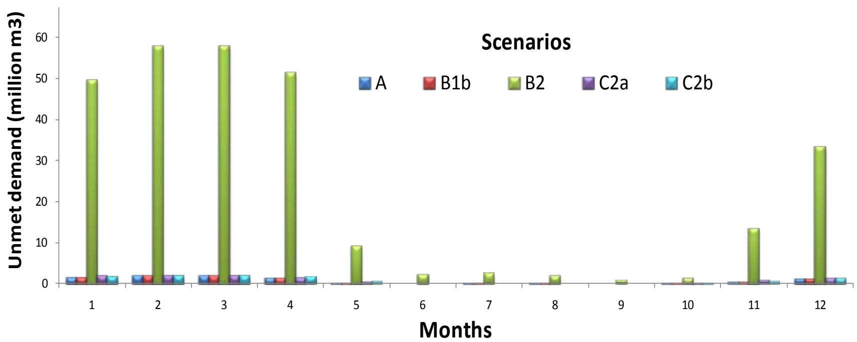

Figure 22: Summary of annual unmet demand in the entire HSB basin

A comparison of unmet water demand in the baseline scenario compared with that in other scenarios shows that expansion of irrigated areas, which use only water from within the HSB basin, increases the demand for water by about 35-60 MCM per year.

5.2.2 Industrial and domestic water use and unmet demand

In the results from all the different scenarios, the demand for domestic and industrial water is completely satisfied for the whole year.

Furthermore, the results indicate that the on-demand irrigation in the entire HSB basin does not change much over time (1990-2030), and it is dwarfed by the demand volumes for agricultural water. In this study, priority and preference are given to agriculture and the remaining water is supplied to household and industrial activities. Therefore, water delivery for all sites is made equitable, and domestic and industrial water requests are met in the HSB basin.

5.3 Climate change

In many climate projections for Thailand, the mean annual precipitation and temperature are shown to increase in the future (Parkpoom *et al*., 2004; ICEM, 2010; SEA START, 2010; Koontanakulvong & Chaowiwat, 2011). This is also the case with the SEA START data, as can be observed in the comparison of baseline rainfall and scenario C2a and C2b rainfall in the WEAP model (Figure 23).

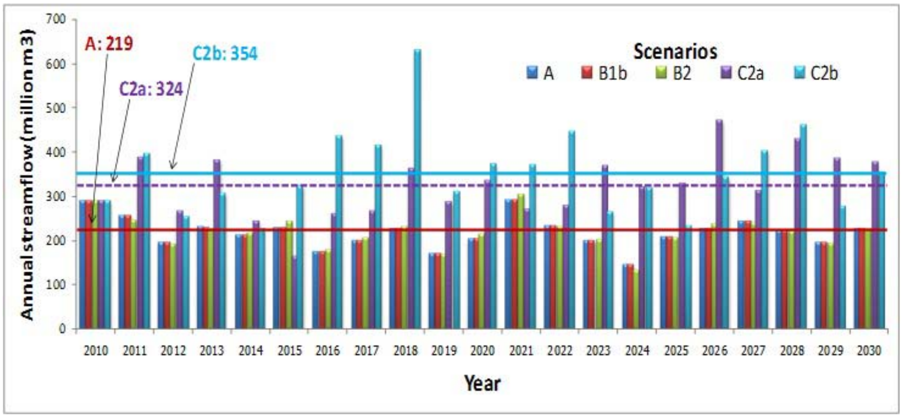

Figure 23: Trend of change in annual streamflow in the HSB basin

The baseline scenario and other four scenarios were compared in order to assess the streamflow in the HSB basin in time series of 20 years (2010-2030) as seen in Figure 15. The results present that the annual streamflow is likely to double in scenario C2a and C2b, especially in June to August each year (Figure 16). WEAP result models that occurrence of change will increase a possibility to large increase in the HSB basin. Other scenarios do not have substantial different in the basin runoff.

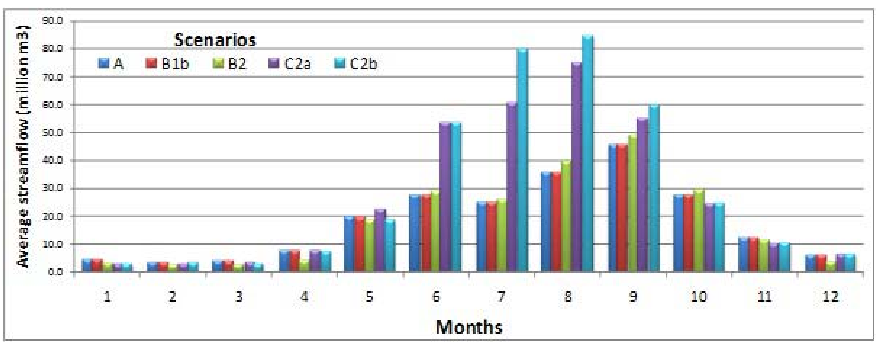

Figure 24: Annual average streamflow in the entire HSB basin under different scenarios

Also expected is an increase in annual rainfall to nearly double in the scenario C2a and more in C2b. Changes in rain quantity in Thailand's monsoon rains can have either beneficial or detrimental effects: they can aggravate flooding and require more expensive flood control measures, increase evapotranspiration rates, increase runoff and cause more soil erosion, with implications for relatively less soil infiltration.

Modelled WEAP results also align with the IPCC (2012) – International Panel on Climate Change report on managing risks of extreme events, in that the **key projections and implications for Southeast Asia under A2 emission scenario** will likely to increase warm days and frequency of heat waves, with the possibility of more frequent and intense precipitation days. Extreme temperatures by the mid-century will increase in frequency from 1 event every 20 years to 1 every 1.5 years, and extreme precipitation by mid-century will increase in frequency from 1 event every 20 years to 1 every 10 years. Thus, there is high confidence that extreme events could affect water management systems. On the other side, the **implications for Thailand under the B2 emission scenario** (SEA START, 2010) is likely to increase minimum temperatures, but to a lesser extent, with the possible trend of a lesser degree of increase in annual precipitation in the future (2040-2059). There is also a tendency toward longer summers, but to a lesser degree compared to the A2 scenario.

5.4 Land-use change

The results from the model runs in WEAP show that, with the current data inputs, there are no significant changes in the streamflow of HSB waterways between the baseline scenario and the land-use change scenario (Figure 25).

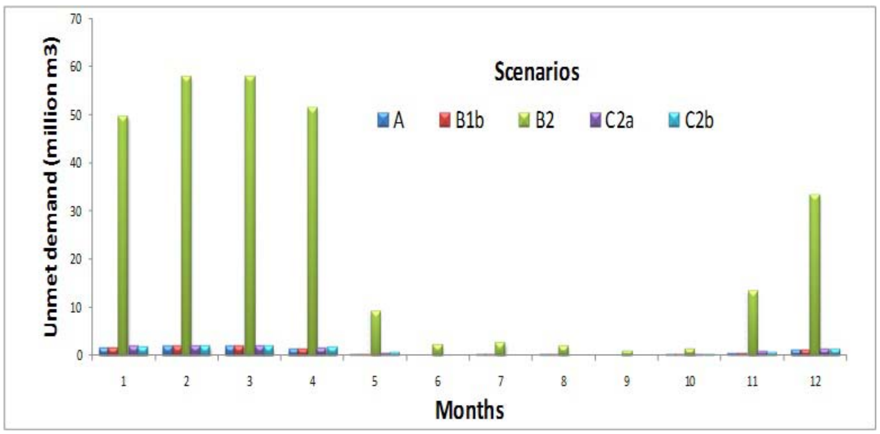

Figure 25: Non-satisfied water demand in the HSB basin under different scenarios

The amount of non-satisfied water demand significantly increases if there is an expansion of irrigated rice and other crop areas in the HSB basin. This is expected to occur only if an irrigation system is considered for use within the basin area, without considering additional water support from other sources. The demand for water increases by about 35-60 MCM in the entire basin.

Nevertheless, with limited investigation at this stage, unmet water demand is not significantly affected by small changes of land use in the basin.

5.5 Water resources development

The potential investment and development of large-scale water diversion from Kong-Loei-Chi-Mun project (scenario D1) would result in water diversion to an irrigation scheme within the local HSB basin, mainly used for agriculture. WEAP models that the HSB will likely experience an increase in water availability for agriculture over next 30 years, and that the annual streamflow will increase on average from 200 MCM to 250 MCM in the entire basin (Figure 26). Meanwhile, the small-scale irrigation scheme scenario D2 will likely decrease annual streamflow to approximately 150 MCM in the future.

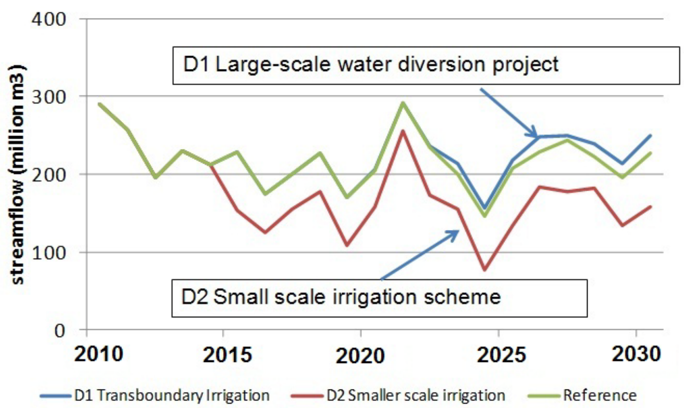

Figure 26: Outflow from WEAP simulated under two water resource development scenarios

Decreases in streamflow, likely for the HSB basin in scenario D2, would result in water shortage in the basin, particularly in areas that are already under stress. The combined impacts of small-scale development and climate change are unknown. Haddeland *et al.* (2005) identifies that irrigation can lead to inefficient use of water because there is frequent and less than optimal water withdrawals, resulting in increased water loss through canopy evaporation; however, this has little effect, as crops are still receiving adequate water to meet their requirements. This is considered in the model with expansions of irrigated areas in the basin.

5. Conclusion

Changing crop types on the same land is unlikely to affect the hydrology to any significant extent. However, expansion of irrigation area in the catchment and large-scale water diversion will strongly affect the hydrology of the catchment . Climate change could also significantly affect basin hydrology through changing precipitation pattern and higher temperature. The effect is most pronounced in the beginning of the rainy season between June and August.

An alternative to large scale water diversion is to further develop the water resources in the basin itself. In this chapter, we consider seasonal storage; that is, transfer over time rather than over space. In our admittedly extreme scenario in which water demand is significantly increased due to a conversion of rainfed area to irrigation, this leads to significant reduction in the outflow. However, a less extreme change will have a smaller effect.

Future agricultural policies and economic growth are likely to affect crop choice. The following factors should be considered: (1) whether anticipated changes are likely to significantly affect the water balance in the basin and (2) whether current shortage can be met or alleviated with the water resources in the basin. Our analysis suggested that there are poverty strategies that do not significantly affect the water balance and current shortages can be alleviated using the water resources in the basin to some extent.

6. Acknowledgements

A previously created draft WEAP model of the study area was provided to this project by Dr. Vichien Plermgamon of the Faculty of Agricultural Engineering, Khon Kaen University. It was devised as part of the Thai-German project on Integrated Water Management and provided valuable insight into existing data, knowledge and model setup possibilities.

7. References

Allen R. G., Pereira L. S., Raes, D., and Smith M., 1998. Chapter 6 - ETc - Single crop coefficient (Kc). In: *Crop evapotranspiration - Guidelines for computing crop water requirements.* FAO Irrigation and Drainage paper **56**, Rome 1998.

College of Population Studies, Chulalongkorn University. Population data from the website of the Population Information Centre: http://www.cps.chula.ac.th/pop_info_2551/eng/pic_en_index.html

Department of Water Resources, 2006. Integrated water resources planning in Chee River Basin Project: Report on Catchment (Catchment code 0415).

FAO. 1988. Runoff efficiency as a function of catchment size. Accessed: http://www.fao.org/docrep/U3160E/u3160e05.htm#3.5 rainfall runoff relationship

Food and Agriculture Organization of the United Nations (FAO). 1998. Crop evapotranspiration – Guidelines for computing crop water requirements. Accessed: http://www.fao.org/docrep/X0490E/X0490E00.htm

Haddeland, I., D. P Lettenmaier and T. Skaugen. 2005. Effects of irrigation on the water and energy balances of the Colorado and Mekong river basin. Journal of Hydrology 324 (2006): 210-223. Accessed: http://tulip.ccny.cuny.edu/~balazs/2010-01%20Papers%20for%20Babak/Haddeland_IrrigationJH_final.pdf

Intergovernmental Panel on Climate Change (IPCC). 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Group I and II of the Intergovernmental Panel on Climate Change (Field, C. B., V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K.L. Ebi, M.D. Mastradrea, K. J. Mach, G. K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)). Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

International Centre for Environmental Management [ICEM]. 2010. Climate change baseline assessment working paper. MRC SEA for Hydropower on the Mekong mainstream. Accessed: http://www.icem.com.au/documents/envassessment/mrc_sea_hp/sea_climate%20change_baseline%20working%20paper.pdf

Koontanakulvong, S. and W. Chaowiwat. 2011. Technical Report: GCM data comparison and its application to water disaster adaptation measures in Thailand. Accessed: http://project-wre.eng.chula.ac.th/watercu_eng/sites/default/files/GCM_Booklet%20_read-ss.pdf

Molle, F and Floch, P. 2008. The "Desert bloom" syndrome: Irrigation development, politics, and ideology in the Northeast of Thailand. Working Paper. Mekong Program on Water, Environment and Resilience, Institute de Recherche pour le Développement, International Water Management Institute. MPOWER, Chiang Mai, Thailand Accessed: http://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers11-03/010044926.pdf

Mutua, F N. 2012. Land Suitability Evaluation for arable crops using GIS and Remote Sensing – Case study: Makueni District, Kenya. Accessed: http://ebookbrowse.com/felix-land-suitability-evaluation-for-arable-crops-using-gis-ppt-d338127797

Naivinit, W. and G Trebuil. 2006. Interactions between water use and labour migration in lower northeast Thailad. Richard, A, P. Caron, J.Y. Jamin, T. Ruf, eds. Coordinations hydrauliques et justices sociales. Actes du seminare PCSI, novembre 2004, Montpellier, France. Cirad, Montpellier France, Colloque. Accessed: http://hal.archives-ouvertes.fr/docs/00/15/37/82/PDF/Warong.pdf

National Economic and Social Development Board, 2010. Impacts of population change in Thailand: situation and policy recommendation (in Thai). Accessed: http://www.nesdb.go.th/temp_social/data/data_02.pdf

Panchaban, S. 1989. Effect of EM on Growth and Yield of Corn. Paper presented at the International Conference on Kyusei Nature Farming. Accessed: http://infrc.or.jp/english/KNF_Data_Base_Web/PDF%20KNF%20Conf%20Data/C1-5-017.pdf

Paiboonsak, S and C. Mongkolsawat. 2007. Evaluating land suitability for industrial sugarcane with GIS modelling. Paper presented at the ACRS 2007. Accessed: http://gecnet.kku.ac.th/research/i_proceed/2550/4_Evaluating_land.pdf

Parkpoom, S., G.P. Harrison and J.W. Bialek. 2004. Climate change impacts on electricity demand. Accessed: http://www.partbrowser.see.ed.ac.uk/~gph/publications/UPEC_Parkpoom_Final.pdf

Samaniego L. & Schulz K., 2009. Supervised Classification of Agricultural Land Cover Using a Modified k-NN Technique (MNN) and Landsat Remote Sensing Imagery. *Remote Sensing*, **9**, [1], 875-895.

Southeast Asia START Regional Center (SEA START), 2010. Preparation of Climate change scenario s for Climate Change Impact Assessment in Thailand. Accessed: http://startcc.iwlearn.org/doc/Doc_eng_15.pdf

Stockholm Environment Institute (SEI), 2011. WEAP Water Evaluation And Planning System – Tutorial. Accessed: http://www.weap21.org/downloads/WEAP_Tutorial.pdf

Wapattanawong, P. and Prasartkul P., 2005. Thai population in the future. Accessed: http://www.ipsr.mahidol.ac.th/IPSR/AnnualConference/ConferenceII/Article/Article02.htm

Watanabe K., Yamamoto T., Yamada T., Sakuratani T., Nawata E., Noichana C., Sributta, A. and Higuchi H., 2004. Changes in seasonal evapotranspiration, soil water content, and crop coefficients in sugarcane, cassava, and maize fields in Northeast Thailand. *Agricultural Water Management*, **67**, 133-143.

CHAPTER 5 Livelihoods Analysis and Modeling

Authors: Eric Kemp-Benedict with contributions from Dusita Krawanchid and Sopon Naruchaikusol

1. Introduction

This study explores the potential impacts on water and land resources, on the one hand, and poverty and livelihoods, on the other, under changing incentives for growing different crops. Specifically, the study is interested in how biofuel incentives might translate to changes in land and water use, and livelihoods. In Southern Thailand, demand for rubber and palm oil—both subsidized by the government—are leading to significant land-use change, including indirect land-use change (Wannasai and Shrestha, 2008), and similar impacts can be expected in Northeast Thailand. The Thai government plans to increase the share of renewable energy in the total energy consumption from just under 10 per cent at present to close to 25 per cent by 2021. Of this, biofuels are expected to replace 44 per cent of petroleum consumption (Preechajarn and Prasertsri, 2012). If implemented, the resulting land-use change could impact upon water resources, in particular for bio-ethanol production (Babel *et al.*, 2011). Bio-ethanol from sugarcane is at present the major biofuel crop in Northeast Thailand, and prices from Thailand are currently low and therefore competitive internationally (Malik *et al.*, 2009).

Over the twenty years of the study—from 2010 to 2030—many other changes will also be taking place in Northeast Thailand and the sub-basin. Continued economic growth in the rest of Thailand offers alternative employment that will draw some people away from the farm, especially young people. Those who remain on the farm might very well want to take advantage of government incentives (and likely future markets) that support biofuel production, but only a few may want to convert all of their land to biofuel production. In the past, the government focused on increasing food production in Northeast Thailand through mineral fertilizer and high-yielding rice varieties to counter soil fertility problems (Tipraqsa *et al.*, 2007). However, alternatives, such as integrated farming or organic vegetable production, have been successfully adopted, sometimes by being persuaded by the example of other farmers (Kasem and Thapa, 2011). Some farmers have found that labour-intensive integrated farming has allowed their children to continue working on the farm (Tipraqsa *et al.*, 2007), but where labour is scarce it constrains the introduction of integrated farming (Kasem and Thapa, 2011).

The model presented in this chapter explores the relationship between land use and livelihoods using a relatively straightforward approach. It uses the results of the household survey and assumes that households in rural areas at different income levels will make choices in the future that are similar to, but not identical to, those they make today. The different scenarios are implemented by specifying how income distribution might change in the future and how land-use decisions might deviate from current patterns. Income levels are generated by specifying the level of income inequality and income growth in the model. Agricultural water use is a consequence of land use, and is calculated in the WEAP model.

2. Methodology

The approach summarized in the introduction addresses the land and water implications of changing biofuels and other crop production in a direct way, but the livelihood implications are indirect. To motivate our chosen approach we note that households follow diverse livelihood strategies, to which the production of a specific crop, such as a biofuel, contributes. In general, and not specifically in HSB, the marginal impact of a particular livelihood activity is ambiguous and difficult to assess, because it contributes to an overall livelihood strategy in a non-linear way. It both constrains and supports other activities, as each activity contributes to and draws on the mix of livelihood assets that households maintain (Bebbington, 1999; DFID, 1999; Soussan *et al.*, 2000).

In the approach for this study we ask, given a change in income distribution, what land-use patterns are consistent with the new distribution. We then assign a greater or lesser role to biofuels or other crops at different income levels in order to capture the potential impact of biofuel incentives. When new crops appear in the overall crop mix in the model, they can be thought of as, in reality, having been both caused by and causing changes in household income that result from the linked package of activities that makes up a household's livelihood strategy.

2.1 Conceptual model

We view households as maintaining or (more typically in Thailand today) increasing their income by adopting livelihood strategies composed of a mix of livelihood activities. As household income increases, we assume that households adopt the characteristics of the households in the category they are entering. Specifically, as discussed later in this chapter, farms with higher incomes tend to have larger farms and have more diverse land cover, not just food crops. They also tend to get more income from non-farm activities. In the scenarios, we assume that as incomes increase across the basin, farmers with higher income either: a) switch to mixed cropping systems; b) switch to energy crops; or c) reforest their land. As a consequence of these land-use choices, differing crop yields and evapotranspiration rates leads to changes in land cover and hydrology.

The series of calculations is shown schematically in Figure 27. As shown in the figure, average income and income inequality (as measured by the Gini coefficient: see, e.g., Champernowne and Cowell, 1999) are used to calculate an income distribution. This is combined with land-use choices at different income levels as estimated from the household survey (and modified in the scenarios) to calculate land cover in the scenario. Within WEAP, this land cover is combined with variables related to climate, runoff, and infiltration, to estimate agricultural water use, groundwater recharge, and streamflow.

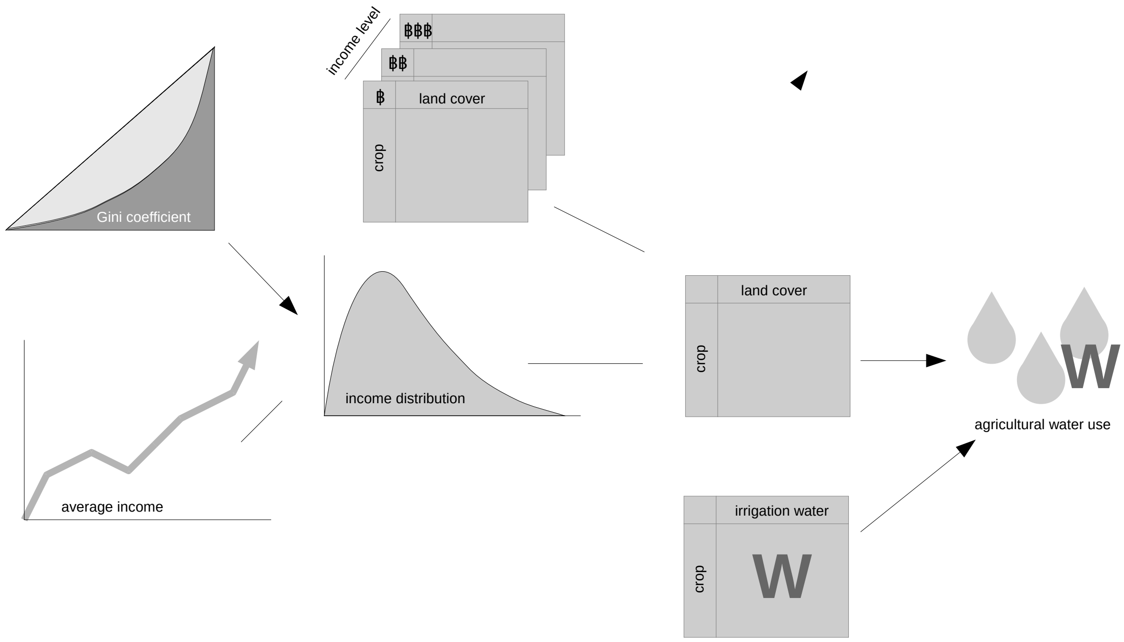

Figure 27: Diagram of the Bayesian model

There are some limitations to the modelling approach we are following. First, by starting from the household survey, we extrapolate from current patterns. In a country that is changing as rapidly as Thailand, this is a questionable assumption. Nevertheless, our household survey suggested that those who remain on the farm (as opposed to those who move to cities) are relatively conservative in their choices. Another limitation is that there is no explicit link in the model to prices or incentives; instead, we imply that they are present or absent by farmers' choice of mixed crops vs. energy crops or forests. As explained above, any particular crop choice will be part of a larger livelihood strategy. A particular strategy will incline a household to either respond or not respond to a particular incentive; we discuss this below with reference to household data. Finally, we do not track chemical inputs and water quality. This choice is dictated by the limits of the available data. This is clearly an important consideration that depends on farmers' choices of crops and livelihood strategies. Regular monitoring of water quality across the basin would be a good investment to make now in order to understand what is happening in this rapidly changing basin.

2.2 Bayesian network model and scenarios

The conceptual model translates directly into a Bayesian network model with a fairly straightforward structure. In a Bayesian network model, all the variables are expressed as discrete probabilities rather than single (point) values. For example, in the model described in this chapter, one important variable is the income group I, which can take on values "very low", "low", "medium", "high", and "very high". The income groups are defined so that at current household incomes each of the five income groups has an equal share (20 per cent) of the total number of households. Viewing this as the probability that a household taken at random will be in one particular income group, we write, e.g., for the "medium" income group,

$$P(I = \text{medium}) = 20\%. \qquad (0.1)$$

Bayesian models build on the concept of "conditional probabilities", which are probabilities that one thing happens (or is true) given that another thing happens (or is true). For example, we will see later that the share of food crops in total farm land *L* for medium-income households is 92.9 per cent. We write this as

$$P(L = \text{food crops} \mid I = \text{medium}) = 92.9\%, \tag{0.2}$$

which is read, "The probability that land is under food crops *given* that the household is in the medium income group is 92.9 per cent."

The total probability that land is under food crops is given by a sum over all income groups,

$$P(L = \text{food crops}) = \sum_I P(L = \text{food crops} \mid I)P(I), \tag{0.3}$$

where the sum is over all of the income groups: very low, low, medium, high, and very high. To represent all possible land covers, we write this in shorthand as

$$P(L) = \sum_I P(L \mid I)P(I). \tag{0.4}$$

In the scenario, we always assume that the income distribution $P(I)$ changes, for example to a new income distribution $P'(I)$, while we may or may not assume any change in the conditional probability of land use (the distribution of land use for each income group). Even if the conditional probability of land use does not change, the overall land distribution will change, because of the change in income distribution, when we calculate

$$P'(L) = \sum_I P(L \mid I)P'(I). \tag{0.5}$$

This is the basic calculation that we carry out in the model: we change the income distribution, possibly change the conditional probabilities for variables of interest, and then compute new distributions for the scenario.

3. Calculations

3.1 Income distribution

A key input to the calculation above is the share of the population within each income group, $P(I)$. We defined income groups by calculating threshold incomes for each 20 per cent of the population in our data set; this gave the income thresholds in Table 4. We then extrapolate to other years using the same income thresholds and assuming that incomes are distributed lognormally.

Table 4: Income classes

	monthly income (baht/hh/month)			agricultural income share (%)	
income class	minimum	median	mean	median	mean
very low	417	1,500	1,446	100	65
low	2,500	3,333	3,480	85	67
medium	4,716	5,792	5,747	63	58
high	7,500	9,167	9,738	56	52
very high	13,399	21,083	28,334	45	54

At the national level, the lognormal distribution has been found to fit income distribution statistics better than other candidate distributions (Kemp-Benedict, 2001; Lopez and Servén, 2006). If the lognormal is a good fit to the project's survey data, then the log of income should be distributed normally. We tested this visually using the plot in Figure 28, which shows the quantiles of our observed log income values, plotted against the theoretical quantiles if the data were normally distributed. If the data is normally distributed then the data should fall along a straight line, which they do, reasonably well. We tested the hypothesis statistically using the Anderson-Darling test statistic as calculated by the nortest R package version 1.0.[4] The Anderson-Darling statistic is recommended as a good omnibus test for normality when the mean and variance are not known (Stephens 1974). The resulting statistic is 0.58, with a p-value of 0.13, which means that at the 10 per cent level we cannot reject the hypothesis of normality; that is, we can treat incomes as approximately lognormal.

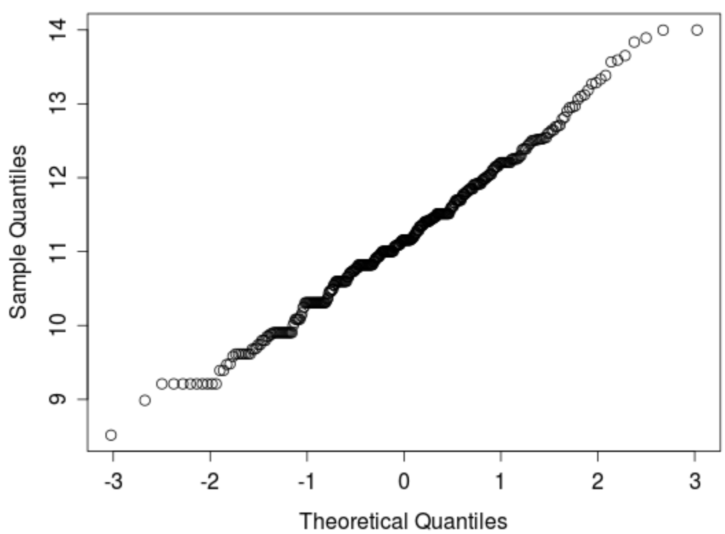

Figure 28: Normal quantile-quantile plot for log of income

The lognormal distribution has two parameters—mean income $\bar{y}$, and the standard deviation of the log of income, σ. The standard deviation of log income is a measure of how unequal, or dispersed, incomes are, and can be related to any other measure of inequality. So, for scenarios we

[4] Available from http://cran.r-project.org/web/packages/nortest/index.html.

need a value for mean income and a value for an inequality measure; we chose the Gini coefficient, G. For a lognormal distribution, the standard deviation of the log of income and the Gini coefficient are related by (Kemp-Benedict, 2001)

$$\sigma = \sqrt{2}N^{-1}\left(\frac{1+G}{2}\right), \tag{0.6}$$

where $N^{-1}(x)$ is the inverse cumulative normal distribution of x. For a lognormal income distribution, the fraction of households within an income bracket $y_a \leq y < y_b$, which we have called $P(I)$ above, is given by

$$P(I_{ab}) = N\left(\frac{1}{\sigma}\ln\frac{y_b}{\bar{y}} + \frac{\sigma}{2}\right) - N\left(\frac{1}{\sigma}\ln\frac{y_a}{\bar{y}} + \frac{\sigma}{2}\right), \tag{0.7}$$

where $N(x)$ is the cumulative normal distribution of x and the symbol I_{ab} refers to the income bracket between incomes y_a and y_b. In the scenarios, both $\bar{y}$ and σ change over time. The model carries out the following calculations:

1. Using the specified Gini coefficient, calculate the standard deviation of log income using Equation (1.6),

2. Using the specified income growth rate r and today's household income $\bar{y}_0$, calculate average income $\bar{y}(t)$ in the future as $\bar{y}(t) = \bar{y}_0\left(1+r\right)^t$.

3. Use the average income and the standard deviation of log income to calculate the fraction of households within each income group using Equation (1.7).

The result of using this algorithm assuming that the historical average rate of household income growth continues and assuming that the Gini coefficient does not change is shown in Figure 29. As seen in the figure, as average income grows, more households join the "very high" income group in the next twenty years, and very few are left in the "very low" income group.

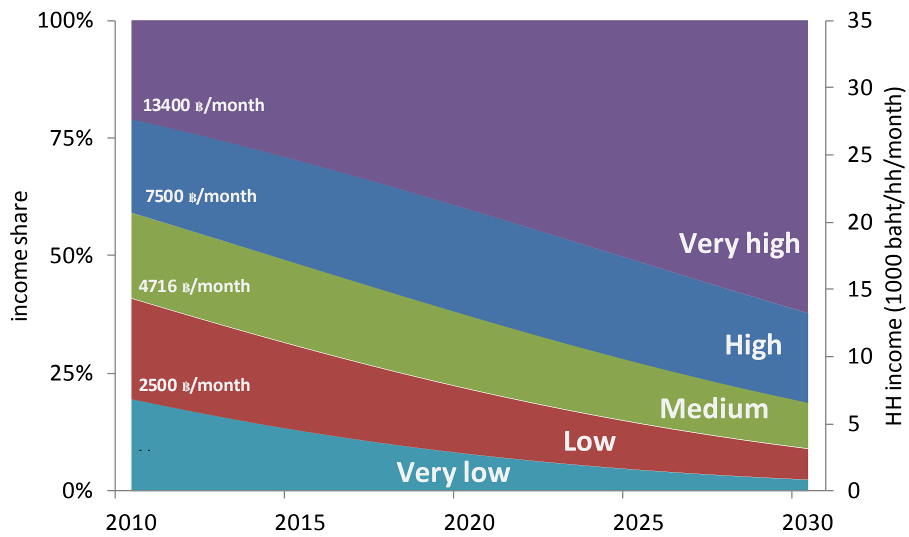

Figure 29: Income distribution at historical income growth rate and constant Gini coefficient.

Gini coefficients for Thailand over time are shown in Figure 30. The open diamonds are historical national data for Thailand, and the closed diamond is calculated from this study's survey data for HSB. As can be seen, the value we estimate for HSB is higher than for the country as a whole. The vertical axis covers the typical range of values observed in national data, from a very low (very equally distributed) value of 25 percentage points to a very high (highly unequally distributed) value of 65 percentage points. For comparison, values for Australia, China, and Sri Lanka are shown on the graph. The figure shows that, historically, the national Gini coefficient has been remarkably stable, but the value for HSB is higher than the national average.

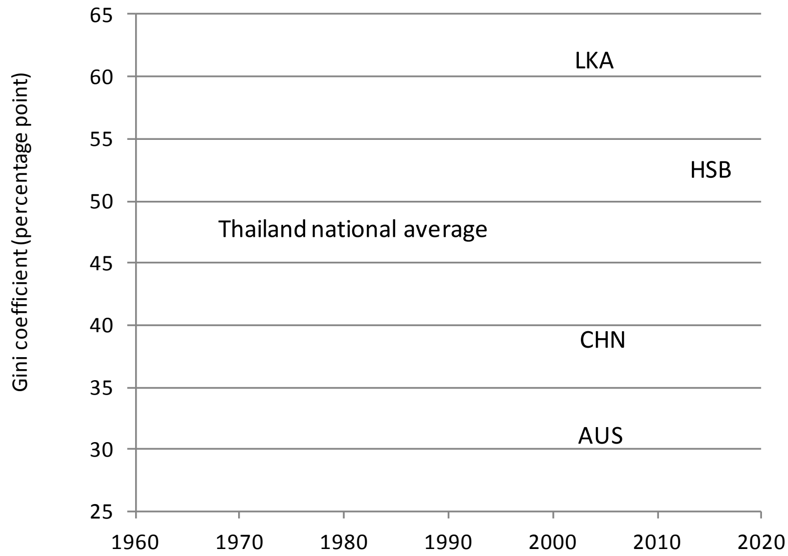

Figure 30: Gini coefficients for Thailand, Australia, China, and Sri Lanka, and for the survey data

Sources: National data: UNU/WIDER World Income Inequality Database WIID 2c (UNU-WIDER, 2008). Time series for Thailand is unadjusted household income from the Thai Socioeconomic Survey as reported in WIID2c. HSB value is from this study's household survey.

Historical average income for Northeast Thailand is shown in Figure 31. As seen in the figure, the region experienced a sharp drop in income between 2004 and 2006, particularly in Khon Kaen. This may be the result of the drought that occurred around that time.

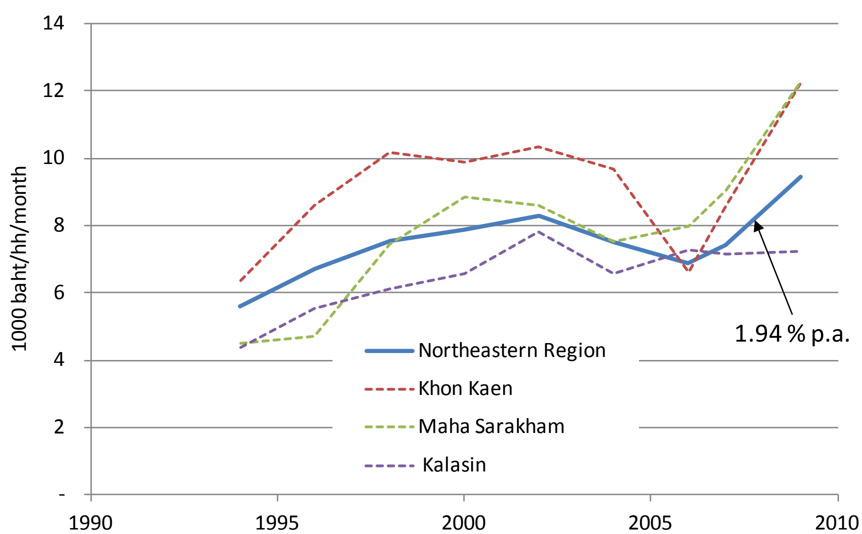

Figure 31: Household income in Northeast Thailand
Source: Thai National Statistics Office (TNSO 2012).

3.2 Poverty

We estimated the poverty headcount using a poverty line. A poverty line is a cutoff income below which a household is considered to be "poor". As in many countries, in Thailand, poverty lines are estimated based on the cost of a food basket. In 2009 the poverty line for Khon Kaen, Maha Sarakham, and Udon Thani were close to 1,230 Baht per person per month (TNSO, 2012). With an average of four people per household, this translates into 4,920 Baht per household per month; this is the poverty line that we used in the model.

With a poverty line at an income level y_p, average income $\bar{y}$, and standard deviation of log income as calculated in Equation (1.6), we can estimate the fraction of the population below the poverty line (the poverty headcount P_{head}) as

$$P_{\text{head}} = N\left(\frac{1}{\sigma}\ln\frac{y_p}{\bar{y}} + \frac{\sigma}{2}\right). \qquad (0.8)$$

3.3 Crop choice

Land use by income group is shown in Figure 32. As seen in the figure, land-use patterns are quite varied in our sample; in particular, the "medium" income group seems to break any kind of trend. This may reflect the particular characteristics of our sample, rather than a real tendency across income groups within the basin. However, it may also reflect a real but temporary pattern that will change as households increase their income generally in the region—for example, if medium income groups are not facing pressures or seeing opportunities to change. However, for the model calculation we assume that the income-specific changes will persist, and estimate land-use cover based on the patterns derived from the survey data set.

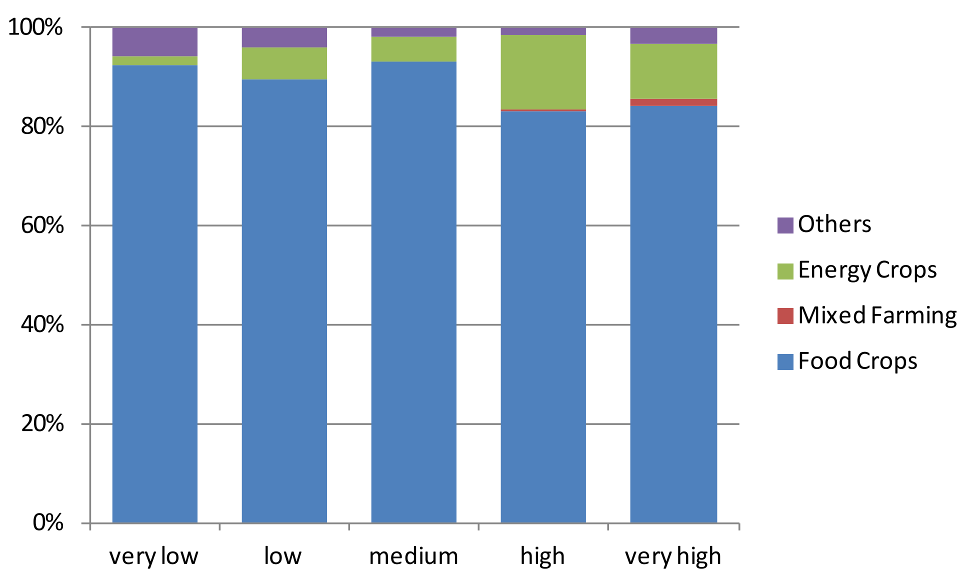

Figure 32: Land use by income group

Interesting insight into land-use change emerged from the household survey, which asked whether farmers respond to incentive schemes for energy crops. Data are shown in Table 5, which shows that, while farmers at all income levels are aware of incentive schemes, few plan to change their farming practice in the next five years because of the schemes. If true, this may be because energy crops are relatively new, and so any farmers willing to respond to the schemes may be “first movers”. If they are successful, then others may follow. Whatever the explanation, it suggests that the incentives are likely to induce only a relatively small proportion of farmers to change their planting strategy.

Table 5: Response to energy crop incentive schemes in the five years following the household survey

	know about incentive schemes		**plan to change because of incentive schemes**	
	yes	**no**	**yes**	**no**
very low	60%	40%	7%	93%
low	72%	28%	4%	96%
medium	73%	27%	0%	100%
high	74%	26%	6%	94%
very high	75%	25%	3%	97%

The household survey and the WEAP model use different land use and land cover classes, and the total areas under comparable classes are not the same. Because the household data is only a sample from the basin, we assume that the WEAP data is correct for the basin. We then followed an algorithm to match the land-use categories, which is described in the Appendix.

3.4 Change in irrigated area

In the survey, interviewers asked whether respondents had experienced a change in the availability of irrigation water and also whether they had changed the area of irrigated land. This allowed us to estimate the responsiveness of farmers to changes in the availability of irrigation water by income group and how that responsiveness might change in the scenario. The results are shown in Table 6. As seen in the table, farmers with low to very high incomes tend to increase their irrigated area or leave it the same when more irrigation water becomes available, with declining responsiveness at higher income. However, farmers with very low income may decrease their irrigated area even with higher availability of irrigation water, suggesting that they face constraints beyond water availability.

Table 6: Changes in irrigated area with change in irrigation water availability

income class	change in irrigation water	change in irrigated area (% of respondents)		
		increase	decrease	constant
very low	increase	10	30	60
	decrease	0	40	60
	constant	0	0	100
low	increase	48	26	26
	decrease	0	80	20
	constant	2	0	98
medium	increase	31	15	54
	decrease	9	82	9
	constant	0	7	93
high	increase	27	17	57
	decrease	0	100	0
	constant	0	0	100
very high	increase	26	15	59
	decrease	0	75	25
	constant	0	4	96

3.5 Household characteristics by income level

The livelihoods model is based primarily on the household survey summarized in Chapter 3 of this report and in the technical background report (Inmuong *et al.*, 2011), supplemented by data from the National Statistical Office of Thailand (TNSO, 2012). We show from the survey results how different household characteristics vary with income. We show the results in a series of tables and graphs, and draw some general conclusions.

As seen in Figure 33, area of land holdings tends to increase with income class, but not dramatically. The spread of the size of land holdings also increases across income groups. Households with very low income have median land holdings of about 10 rai, with a maximum of 40 rai. The median land holding for very high income households is about 20 rai, while the maximum is close to 70 rai, so that both the median and maximum are close to twice that of a household with very low income.

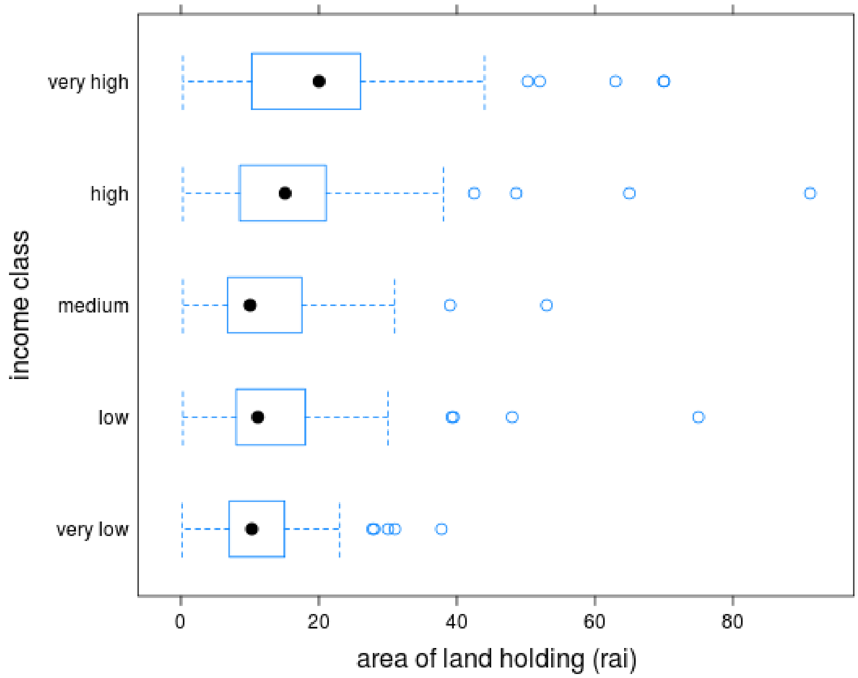

Figure 33: Size of landholding for different income groups

As discussed above, the crop mix varies across income groups, and does not follow a systematic trend in our data set. However, when considering low-income households (those in the "very low" and "low" income categories) separately from other households, the pattern is more distinct, as shown in Figure 34. As seen in the figure, all households devote most of their land area to food crops (mostly rice), but higher-income households diversify more than lower-income households into different types of crops. One interesting feature is that mixed farms appear to be an option for higher-income households, but not lower-income households.

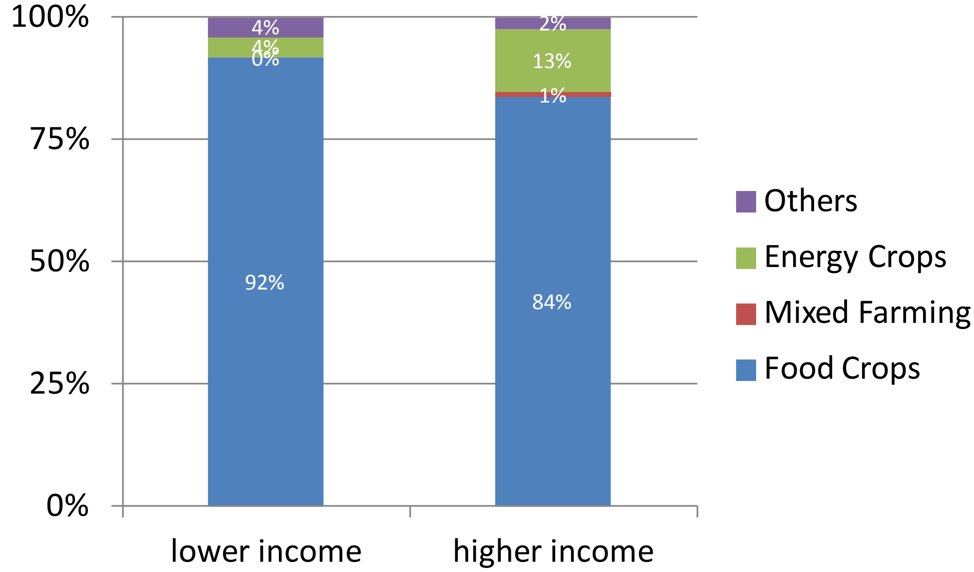

Figure 34: Land use for lower-income and higher-income households

The trends shown in Figure 34 can be seen in more detail in Table 7, which also shows the area taken up by buildings at different income levels. The area is a relatively large fraction at very low incomes because of small land holdings; it decreases as income goes up except at very high income levels, presumably because those households can afford more extensive buildings and engage less in agriculture.

Table 7: Land distribution by income class

	land area distribution (%) by income class				
land cover	**very low**	**low**	**medium**	**high**	**very high**
Food crops	92.4	89.6	92.9	83.2	84.0
Energy crops	1.6	6.1	5.2	14.9	11.0
Mixed farming	0.0	0.0	0.0	0.3	1.6
Fallow	0.9	0.7	0.0	0.0	0.2
Orchard	0.0	0.0	0.2	0.0	0.0
Forest	0.0	0.0	0.0	0.2	0.2
Water body	0.0	0.0	0.2	0.0	0.0
Buildings	3.4	1.3	1.4	1.2	1.5
Grass for forage	0.0	0.5	0.1	0.0	0.0
Livestock	1.6	0.0	0.0	0.0	0.2
No response	0.0	1.7	0.0	0.1	1.2
Total	100.0	100.0	100.0	100.0	100.0

Consistent with increased diversification of land use at higher income, higher-income households also tend to diversify into non-agricultural activities more than do lower-income households. This is shown in Figure 35. As seen in the figure, the median very low income household (the black dot) derives 100 per cent of its income from agriculture. The median very high income household, by contrast, derives less than one-half of its income from agriculture. However, at all income levels there are households in our data set that derive either 100 per cent or zero per cent of their income from agriculture.

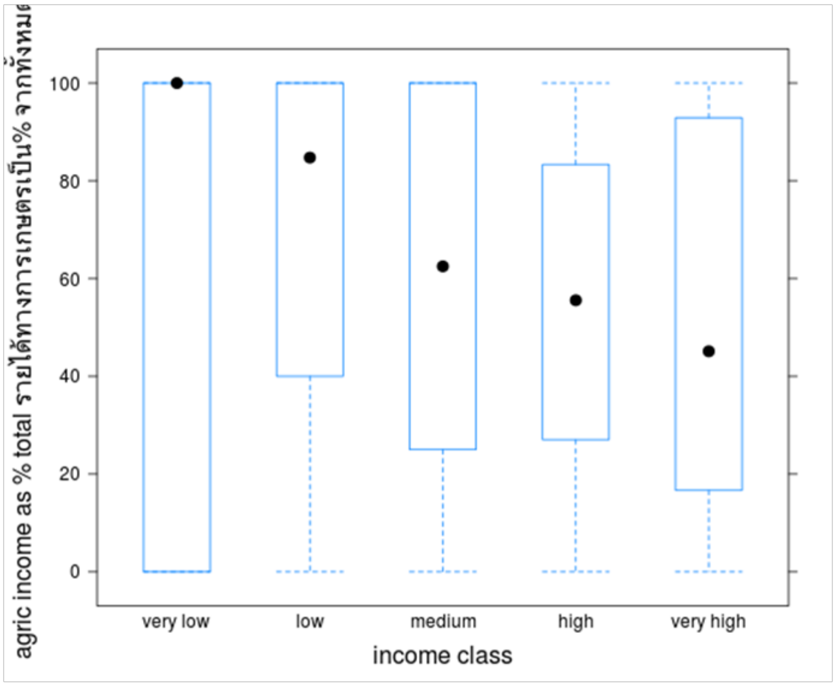

Figure 35: Agricultural income as a share of total income by income group

4. Scenarios and Results

In the scenarios described in this chapter, we explored the transition from food crops into either mixed cropping systems or energy crops under different levels of income inequality. We assume that farmers transition away from food crops into alternatives as their income increases, consistent with Figure 34, and then use a scenario parameter to specify to what degree the change is directed toward mixed cropping systems or energy systems.

Average household income growth was the same in all the scenarios, equal to the historical average from 1994 to 2009 of 1.94 per cent per year. Income inequality was specified by assuming that inequality stays the same; falls toward the national average; or grows. These alternative paths are shown in Figure 36.

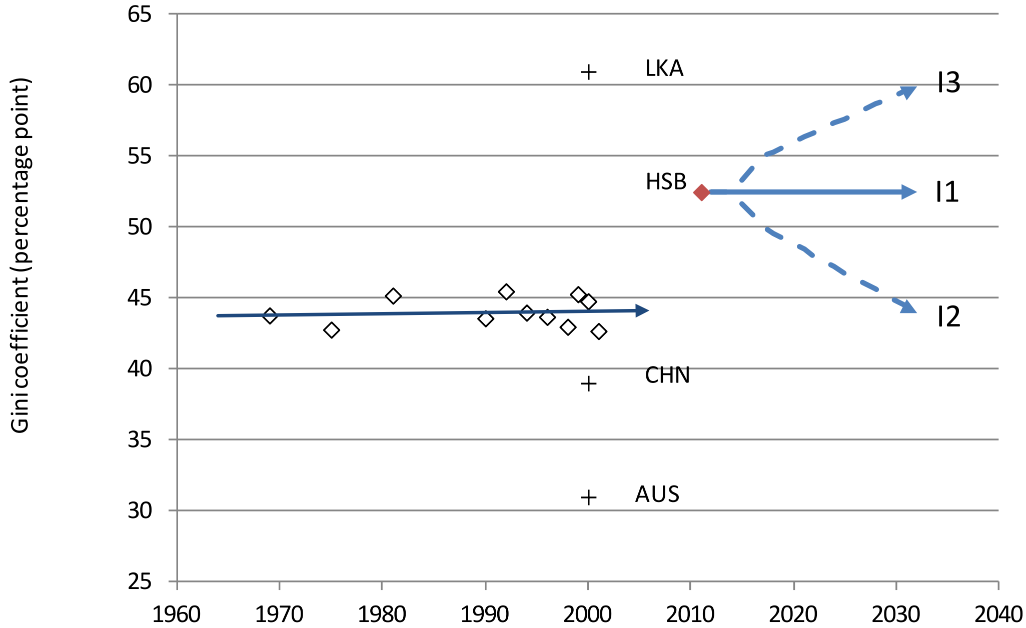

Figure 36: Income inequality scenarios

The implications for poverty are shown in Figure 37. Keeping income inequality at its current level (I1) leads to only a modest drop in the poverty rate. If it drops toward the national average (I2), poverty drops more quickly, reaching about half its current estimated level by 2030, but it still remains high. Finally, in a scenario in which inequality increases (I3), the poverty rate remains almost the same as today, despite continued economic growth.

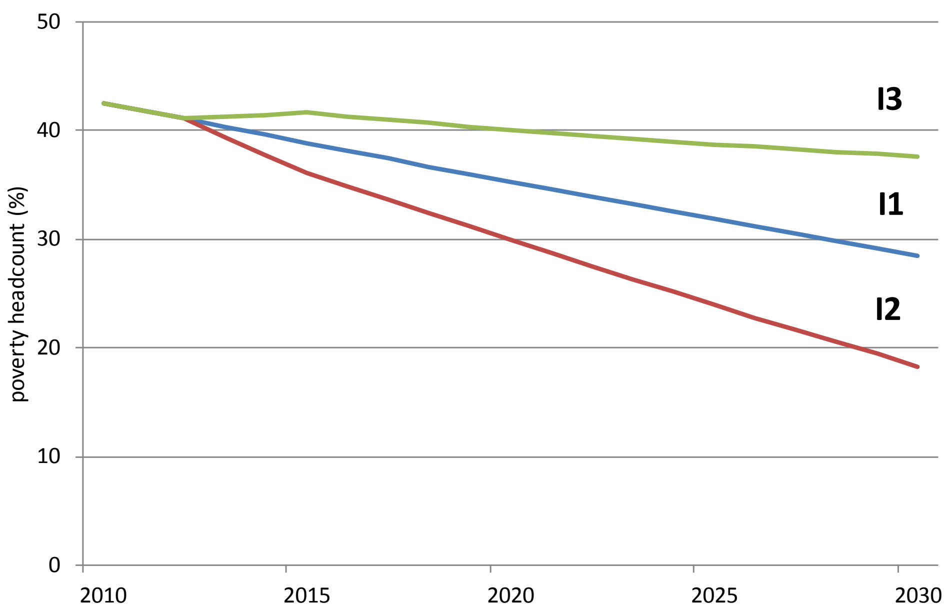

Figure 37: Poverty in the inequality scenarios

The land use and hydrological impacts estimated from the model are modest. An example of land cover change is shown in Figure 38, which contrasts the low-inequality scenario I2 with the high-inequality scenario I3 under conditions where integrated farms are preferred over energy crops. As can be seen in the figure, the model suggest only small differences in the area under the different crops by the end of the scenario, a reflection of the relative stability of land use that has been seen in the past, even in the presence of incentives.

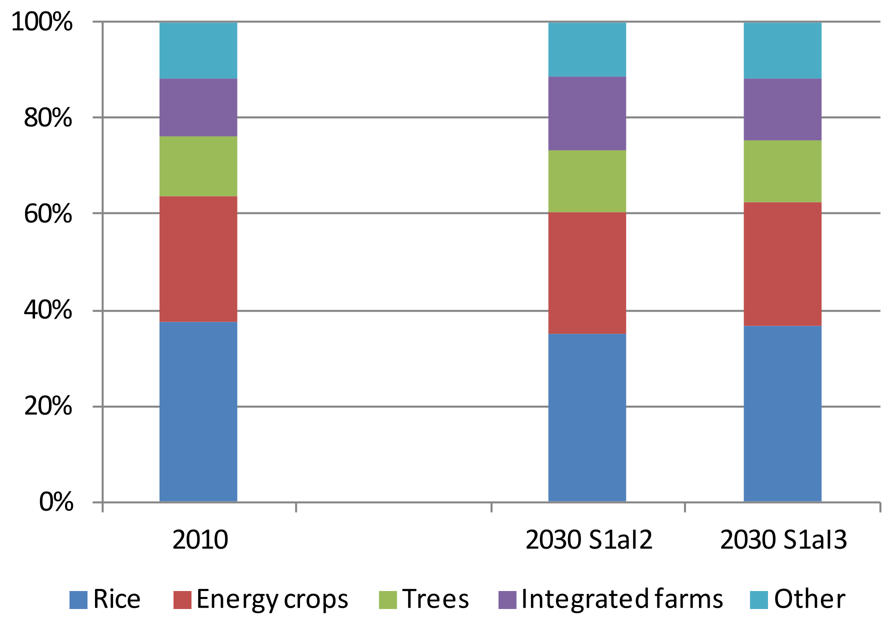

Figure 38: Land cover change in two scenarios

Impacts on hydrology are also modest, as seen in Figure 39. In no case does streamflow decrease significantly, but even the increases are quite small, amounting to about 2 per cent of total annual discharge.

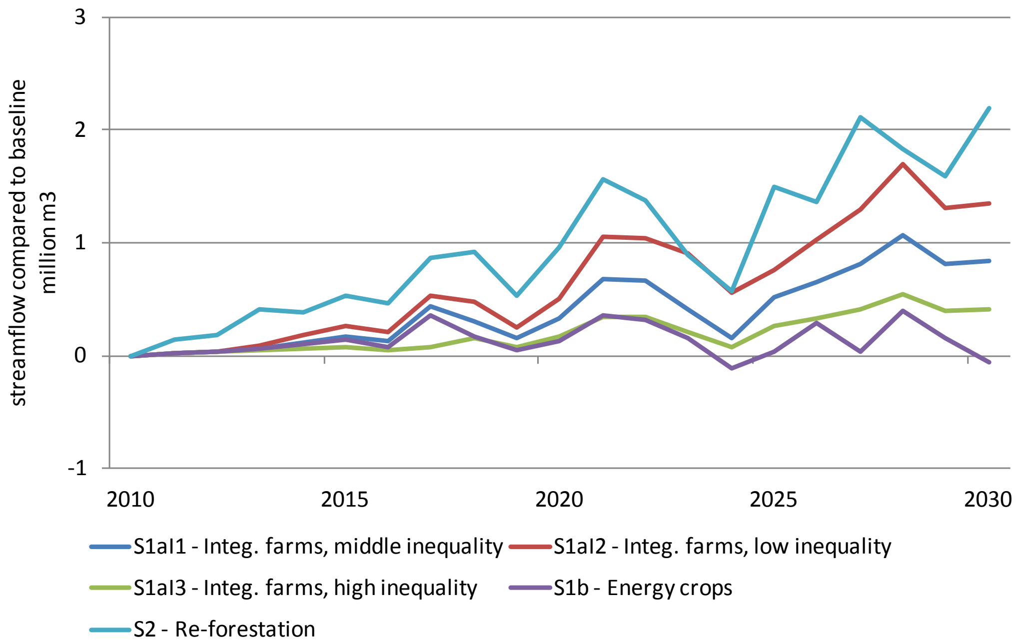

Figure 39: Hydrological impacts of inequality and land use change

5. Observations and Conclusions

All of the scenarios feature a transition away from rice as a share in total cropped area, but rice remains an important part of farming activity throughout all the scenarios. Moving out of rice has the most important influence on the hydrology, and mainly results in more streamflow. Nevertheless, the impact on streamflow is modest in all scenarios. We note that these outcomes depend on past trends persisting into the future. If, for example, there is a major shift toward large commercial farms, and most smallholders are displaced, then the consequences for land use, hydrology, and livelihoods would be quite different from what the model suggests.

We note that our results contrast with those of Babel *et al.* (2011), who constructed a SWAT model to look at the hydrological impacts of biofuel expansion in Southern Thailand. Their model suggested substantial changes in hydrology, with increases in surface runoff of about 13 per cent and reduced baseflow. They found the strongest change would come from bioethanol production. Our results differed from theirs, we believe, for two reasons. First, all of the bioethanol expansion is at the expense of rice. While sugarcane is, indeed, highly water-demanding, rice is as well, and the net effect on evapotranspiration of shifting from rice to sugarcane is small. The other reason is that we assumed that farmers are relatively conservative in their land use choices, an assumption that is grounded in our household survey results. So, where Babel *et al.* assumed a complete shift from one land cover to another, we assume only partial shifts.

Regardless of its impact on land and water, levels of inequality and land ownership can significantly affect poverty and livelihoods, and even with declining income inequality, poverty rates remain quite high. This suggests that in future planning for regional economic growth, careful attention should be paid to the distributional impacts of different policies. Although we hesitate to make any strong recommendations on economic policy on the results of this model, it suggests that "balanced growth", in which income inequality remains at current levels, is not the best strategy for the area.

Instead, to the extent possible, strategies that promote economic growth while also reducing inequality would be preferable.

6. References

Babel, M. S., Shrestha, B. and Perret, S. R. (2011) 'Hydrological impact of biofuel production: A case study of the Khlong Phlo Watershed in Thailand'. *Agricultural Water Management*, 101(1). 8–26. doi:10.1016/j.agwat.2011.08.019.

Bebbington, A. (1999) 'Capitals and Capabilities: A Framework for Analyzing Peasant Viability, Rural Livelihoods and Poverty'. *World Development*, 27. 2021–44. doi:doi: DOI: 10.1016/S0305-750X(99)00104-7.

Champernowne, D. G. and Cowell, F. A. (1999) *Economic Inequality and Income Distribution*. Cambridge University Press, Cambridge, UK.

DFID (1999) *Sustainable Livelihoods Guidance Sheets*. UK Department for International Development, London.

Inmuong, U., Rayubkul, J., Srikuta, P. and Bush, A. L. (2011) *Final Report: Survey of Rural Household Livelihoods in Sub-river Basin, North East Thailand, Exploring Mekong Region Futures Project*. Faculty of Public Health, Khon Kaen University, Khon Kaen, Thailand.

Kasem, S. and Thapa, G. B. (2011) 'Crop diversification in Thailand: Status, determinants, and effects on income and use of inputs'. *Land Use Policy*, 28(3). 618–28. doi:10.1016/j.landusepol.2010.12.001.

Kemp-Benedict, E. (2001) *Income Distribution and Poverty: Methods for Using Available Data in Global Analysis*. PoleStar Technical Note, 4. Stockholm Environment Institute, Boston, MA.

Lopez, H. and Servén, L. (2006) *A Normal Relationship? Poverty, Growth, and Inequality*. World Bank, Washington, D.C. file://refs_transfer/PDF_GDRs/LopezAndServen2006_wps3814-0647611904/LopezAndServen2006_wps3814.pdf.

Malik, U. S., Ahmed, M., Sombilla, M. A. and Cueno, S. L. (2009) 'Biofuels production for smallholder producers in the Greater Mekong Sub-region'. *Applied Energy*, 86, Supplement 1. S58–S68. doi:10.1016/j.apenergy.2009.04.048.

Preechajarn, S. and Prasertsri, P. (2012) *Thailand Biofuels Annual 2012*. GAIN Report, TH2064. USDA Foreign Agricultural Service, Global Agricultural Information Network, Washfington, D.C.

Soussan, J., Blaikie, P., Springate-Baginski, O. and Chadwick, M. (2000) *Understanding Livelihood Processes and Dynamics*. Leeds School of Geography, Leeds, UK. file://C:/refs_transfer/PDF/Soussan et al 2000-3768263211/Soussan et al 2000.pdf.

Stephens, M. A. (1974) 'EDF Statistics for Goodness of Fit and Some Comparisons'. *Journal of the American Statistical Association*, 69(347). 730–37. doi:10.2307/2286009.

Tipraqsa, P., Craswell, E. T., Noble, A. D. and Schmidt-Vogt, D. (2007) 'Resource integration for multiple benefits: Multifunctionality of integrated farming systems in Northeast Thailand'. *Agricultural Systems*, 94(3). 694–703. doi:10.1016/j.agsy.2007.02.009.

TNSO (2012) 'TNSO home page'. *Thailand National Statistical Office*. http://web.nso.go.th/.

UNU-WIDER (2008) 'World Income Inequality Database (WIID2c)'. http://www.wider.unu.edu/research/Database/en_GB/wiid/.

Wannasai, N. and Shrestha, R. P. (2008) 'Role of land tenure security and farm household characteristics on land use change in the Prasae Watershed, Thailand'. *Land Use Policy*, 25(2). 214–24. doi:10.1016/j.landusepol.2007.07.003.

7. Appendix: Allocating crop shares

This appendix explains the algorithm used in the model to allocate crop shares. The algorithm rectifies the differences between the shares under the WEAP crop categories and those of the household survey. It therefore includes two sets of land-use categories: WEAP crops, shares of which are denoted by σ_i, and household survey crops, which are denoted by s_i. The household survey crop categories are further broken down by income group j, giving $s_{i,j}$. Denoting income shares by y_j, crop area shares can be calculated

$$s_i = \sum_{j=1}^{m} y_j s_{i,j}, \tag{0.9}$$

where $m = 5$ is the number of income groups.

Two of the WEAP crops, sugarcane and cassava, correspond both to energy and to food crops. A fraction f of these crops is assumed to be for food, and $1-f$ for energy, with the same allocation for each crop. So,

$$\begin{aligned} \sigma_{\text{energy}} &= (1-f)(\sigma_{\text{sugar}} + \sigma_{\text{cassava}}) \\ \sigma_{\text{food}} &= \sigma_{\text{rice}} + f(\sigma_{\text{sugar}} + \sigma_{\text{cassava}}). \end{aligned} \tag{0.10}$$

In future years, we calculate

$$s'_{\text{food}} = \sum_{j=1}^{m} y'_j s_{\text{food},j}, \tag{0.11}$$

so that the income-group specific shares for food crops stay the same, while the income shares themselves change. We then calculate the new allocation for WEAP shares by applying the change in the odds ratios. To do this, first we calculate

$$R \equiv \frac{s_{\text{food}}}{1 - s_{\text{food}}}, \tag{0.12}$$

with the corresponding odds ratio R' for future years. Then we set

$$\frac{\sigma'_{\text{food}}}{1-\sigma'_{\text{food}}} = \frac{R'}{R} \frac{\sigma_{\text{food}}}{1-\sigma_{\text{food}}} \equiv x. \tag{0.13}$$

From this equation, the new share σ'_{food} is given by

$$\sigma'_{\text{food}} = \frac{x}{1+x}. \tag{0.14}$$

Next, we define a scenario parameter θ that distinguishes between integrated/mixed farms and energy crops with a change in food crops. Specifically,

$$\begin{aligned}\sigma'_{\text{mixed}} &= \sigma_{\text{mixed}} + \theta\left(\sigma_{\text{food}} - \sigma'_{\text{food}}\right)\\ \sigma'_{\text{energy}} &= \sigma_{\text{energy}} + (1-\theta)\left(\sigma_{\text{food}} - \sigma'_{\text{food}}\right).\end{aligned} \tag{0.15}$$

In the integrated/mixed cropping scenario, all other shares remain the same. Rice changes in proportion to total food, so

$$\sigma'_{\text{rice}} = \frac{\sigma'_{\text{food}}}{\sigma_{\text{food}}}\sigma_{\text{rice}}. \tag{0.16}$$

Because of this proportionality, from Equation (1.10) the new value of f, f', is given by

$$\frac{f'}{1-f'} = \frac{\sigma'_{\text{food}}}{\sigma'_{\text{energy}}}. \tag{0.17}$$

Also from Equation (1.10), the ratio of the total share of sugarcane and cassava in the future to the current value is given by the ratio

$$\frac{\sigma'_{\text{sugar}} + \sigma'_{\text{cassava}}}{\sigma_{\text{sugar}} + \sigma_{\text{cassava}}} = \frac{\sigma'_{\text{energy}}}{\sigma_{\text{energy}}}\frac{1-f}{1-f'}. \tag{0.18}$$

Keeping the relative amount of sugarcane and cassava the same as in the base year, this implies that

$$\sigma'_i = \frac{\sigma'_{\text{energy}}}{\sigma_{\text{energy}}}\frac{1-f}{1-f'}\sigma_i, \tag{0.19}$$

where i is either “sugar” or “cassava”.

CHAPTER 6 Policy Engagement and Recommendations

Authors: Yanyong Inmuong, Angela Bush, Chayanis Krittasudthacheewa

6.1 Background: Development policy framework in Thailand

Development of national policy and planning process in Thailand is done by both the National Economic and Social Development Board (NESDB) and sectoral ministries. The NESDB has a functional role in producing and processing the Five-year National Social and Economic Development Plan which is aimed as a guide for all ministries and local governments within the country in their activities that strive to fulfil their respective mandates. The Five-year National Social and Economic Development Plan typically addresses the development vision and mission of the country, as well as outlines the development approach of key issues relating to the ministries. Each ministry then translates the NESDB development guidance into its own Five-year Ministerial Policy Plan which includes a list of activities for which budget support is sought from the central government. Once each sectoral ministry has finished its draft Five-year Policy Plan, it is sent to the NESDB and Budget Bureau for comments and approval. Once approval has been gained, each ministry makes its annual development activities plan and budget list, which is submitted to the Cabinet, seeking comments and approval. Once the Cabinet has approved the ministerial annual development activities plan, the respective Ministers will submit their plans to Parliament for final approval. Typically, the ministerial annual plan has to be completed three years prior to submitting the plan to Parliament.

6.2 Water resources development: a cross-sectoral challenge

Water resource development issues are viewed by the NESDB as cross-cutting policy areas and therefore the NESDB requires all concerned ministries to be involved in the implementation of planned activities. The key players in development activities for water resources are the Ministries of: Agriculture and Cooperatives, Natural Resources and Environment, the Interior, and Energy. Each ministry shapes its water development plan and activities according to its legitimate role and mandate. The Ministry of Agriculture and Cooperatives is responsible for water supply to farmlands within irrigated areas; the Ministry of Natural Resources and Environment provides water to farmlands outside irrigated lands and builds water supply plants for communities at the sub-district level; the Ministry of the Interior manages water resources for affected communities during drought and flood conditions; and the Ministry of Energy is in charge of controlling and managing hydropower dams.

As water development activities are limited to individual ministry mandates and integration of water policies and plans between ministries is rare, the Thai Government established the National Water Resources Committee (NWRC) in 2007 to play a cooperative role in overseeing the country's water resources development policies and river basin planning. The NWRC is chaired by the Prime

Minister, the Natural Resources and Environment Minister acts as the Vice Chair and the Director General of Water Resources is the NWRC Secretary. The NWRC has since established 25 River Basin Committees (RBCs) and in turn these RBCs set up Sub-RBCs to oversee water development activities within individual watersheds.

The NWRC has a mandate to advise the Cabinet on water policy, planning, budget, and legal framework improvement. The NWRC, in conjunction with the RBCs, embraces Integrated Water Resources Management (IWRM) as a conceptual framework for reviewing and improving current country water policy and plans in order to best advise the Cabinet.

The RBC has its own responsibilities too, which are: to inform the NWRC on river basin water policies, plans and development strategies; to coordinate any water resource development plans and projects within a given river basin boundary; to prioritize the river basin water resource use by different sectors; and to assess any water resource development projects undertaken by government authorities. Typically, in the early stage of the planning process, the provincial and local governments who develop water resource development projects must submit detailed plans to the RBC for review. The RBC will then set up a Sub-RBC to review and comment on the proposed project. Next, the provincial and local governments must submit the project plans to their respective ministries for approval and for inclusion in the draft Ministerial Annual Development Plan, which will be further reviewed and approved by the NESDB and Budget Bureau prior to submission to the Cabinet.

In practice, the NESDB will review any water resource development project using the criteria and frameworks noted in the Five-year Plan. The NESDB oversees a broad spectrum of social and economic development goals of which the water development plans and projects are just one part. The NESDB largely sees water as a resource input for production activities and emphases a management approach that copes with scarcity when reviewing sectoral development plans. The NWRC and RBC, however, take water quantity and equitable use of water by different sectors to be their benchmarks for such reviews. Up to now, it is very rare that the NESDB, NWRC and RBC will take into consideration the three integrated domains of water, food and energy when reviewing proposed water development plans and projects.

6.3 Policy engagement of the NE Thailand (HSB) study with policy planning

Since the inception of the northeast Thailand local study component of the Exploring Mekong Region Futures project, the researchers intentionally identified the need for national (NESDB) and regional (RBCs) policy and planning organizations to get involved in implementing the project activities. This process of involvement was primarily aimed at sharing and exchanging information and experiences through undertaking project activities together.

Fortunately, during the early phase of project implementation, the Thai government had started to draft the 11th National Social and Economic and Development Plan (2012-2016), [5] for which the

[5] http://www.nesdb.go.th/Portals/0/news/plan/p11/Plan11_eng.pdf

NESDB played a central role in extracting information from stakeholders regarding suggestions for development directions for the country over the next five years. The NESDB also organized four regional meetings across the country; the meeting for the northeast was held in Khon Kaen Province on 12-13 March, 2011. The NESDB invited the one representative of the project team, Dr. Yanyong Inmuong, to lead a forum on the proposed framework for natural and environmental resource development relating to the 11th NESDB Plan. This forum was attended by stakeholders from the national and northeast region levels, with a total of 366 participants. Dr. Yanyong brought up the issue of balancing the cultivation of crops for food and those for energy, as well as the risks associated with climate variability impacts. The meeting participants discussed food and energy resource issues extensively and eventually agreed to put forward the issue as another five-year national development agenda framework (refer to Chapter 5 of NESDB plan, 2012-2016). Some participants also identified that in the near future Thailand will require better development of policy and planning tools for the food and energy sectors. The need for planning tools suited our project activities, especially the scenario development through modelling the water-food-energy nexus in the HSB case study area (see Chapters 4 and 5 of this report).

In addition to project's influence within policy-making at the national level, regional planners have also been touched by this work. Some of the Chi River Basin Committee members have been appointed by their Chairperson (also the Khon Kaen Provincial Governor) as a taskforce to collaborate with the northeast local study in HSB and they work with researchers in implementing many project activities (activity planning, information surveys, meeting workshops, etc.). These RBC members were able gain more experience and skills and better understanding of climate by participating in WEAP and BBN model workshops and trainings. Additionally, the Chi RBC introduced some reforms by incorporating the notion of the water-food-energy nexus into their rolling three-year strategic water resources development plans in September 2011. This three-year plan then accordingly influenced the implementation framework of the annual regional and provincial water resources development action plan.

6.4 Policy recommendations

This project has introduced some ideas about possibilities of future changes to HSB climate, land use, family income and poverty dimensions. Consequently there are implications for future development of policies at the national, regional and local levels. The following recommendations are derived both from comments from the participants of project workshops and from the reflections of the project researchers.

Climate variability has gradually but extensively affected farming systems and local farmers are therefore more at risk of crop yield reduction as well as livelihood impacts. The government should initiate a climate information support system available for use by RBCs, provincial, district, local governments and farmer groups in land-use planning and decision-making (e.g. crop types and appropriate cultivation periods).

A trend of farmers switching from rice to biofuel crops (e.g. sugarcane and cassava) was observed in the study area and is expected to expand and continue in the future, which may pose high risks to food security. Expansion of commercial energy crops can also lead to scarcity of both surface water and groundwater resources within the watershed, hence crop zoning and proper planning for sustainable use of available public water resources are essential. The study results demonstrate that many farmers tend to switch crops in response to market demand and related produce prices, while disregarding limitations of soil quality and water resources. The RBC, provincial, district, and local governments should produce a local database and information centre to advise and deliver services to these farmers for more informed decision-making.

Even though the RBC was established to administer the water resources development framework of each catchment and also to inform the National Water Resources Committee of any developments of policy and planning issues, these tasks are largely still constrained within provincial areas, rather than watershed boundaries. Therefore, the next water resources development framework should be redirected to watershed boundaries with incorporation of provincial scale connectivity. This will improve the effectiveness of water resource management as transboundary flows and water sharing will be better documented.

The study results also revealed a widening inequity in the distribution of wealth within the community, where small farmers are more vulnerable to the effects of poverty. We suggest that a detailed investigation is needed, particularly on the farm scale, into how families can optimize their income. Community leaders who participated in the project activities recommended that relevant government and non-government organizations should conduct further study on how the farmers could best manage their own resources (land, water, plant, labour, etc.) at optimum scales to gain more yield per land area and to increase sustainability of family income. Of specific interest are organic plants and organic farming, which may produce products with more profitable sale prices. Additionally, the provincial, district and local governments should promote off-farm dry season jobs for these poorer farming households. It would be beneficial for government agencies to attract manufacturers to the northeast to create more local off-season jobs, so as to increase family income and reduce poverty.

Another finding of this work is the expansion of rubber and biofuel crop areas in HSB, potentially at the expense of forested lands or areas of remnant vegetation. Therefore, there is a need to preserve existing forest lands and biodiversity conservation areas. The local government should initiate land-use policies and planning for ecological restoration and conservation. This will have the added benefit of maintaining soil moisture content and reducing erosion to conserve local water resources.

As many farmers in the study area use chemical fertilizers without any crop rotation or organic inputs, there are risks of further degradation of the northeast's already poor soils in the long-term. Hence, it is recommended that the national government promotes and subsidizes farmers to apply organic fertilizer more widely and rejuvenate land fertility. Farmers should also be informed on the necessity of soil, water and forest conservation at farmland and community scales, and how use of agrochemicals can impact the environment.

Lastly, the national government should review water resources development plans by not only focusing on large-scale projects, but also promoting small irrigation projects at farmland and village scales.

CHAPTER 7 Most Significant Changes Stories

Authors: Phatcharee Seekuta and Angela Bush

After conducting four workshops, comprising two scenario building workshops and two opinion and belief monitoring workshops, the project team approached several key stakeholders who were participants in these events to ask them about how the experience may have affected them. The telephone interviews were conducted on the 5th of September by the researcher who acted as organizer and master of ceremonies to all the events, and was therefore familiar to all the stakeholders. Six participants were asked what they thought were the most significant changes from their participation in the project activities, how they may have changed, and why they think these changes were significant for them. The responses given by the six respondents are given below, along with their organizations and affiliations.

Ms. Kannika Chuntaburi

Position: Policy and Plan Analyst (Professional Level)

Organisation: Northeastern Region Economic and Social Development Office (NESDB)

Ms. Kannika did not observe any tangible changes, but rather, she realized that policies need to be developed and formed with an evidentiary basis from scientific research. This would enable better policy development than the usual top-down policy approach, because policy makers need to analyse relevant evidence and also consider participation from locals (bottom-up inputs) while making decisions.

Mr. Ukrit Supasethapong

Position: Chairman

Organisation: HSB Working Group

In the beginning, Mr. Ukrit expected that some improvements to the irrigation infrastructure of HSB might be the outcome of this project, but then he realized that the project aim was quite different. Now, he understands that the project is not just about HSB, but that it relates to other countries too, which he in turn explained to the HSB Working Group. He also now understands that there are many factors that influence the success of development projects, especially budget and impacts from other countries.

Since participating in the workshops, Mr. Ukrit thinks that those working on water resource management within HSB should focus on self-sufficiency first, before asking for help from outsiders. In his role as a rice farmer, he now believes that he will carefully plan his activities before planting in order to avoid production failure. He will pay more attention to the potential variability of climate and the uncertainty that it brings.

Dr. Jongkon Pimwapee

Position: Chairman

Organisation: Kong Chi Mun River Basin Organization

Dr. Jongkon believes research is important for building a strong evidence base to create a clear policy framework which relates to the needs of local people. This should apply not only to the Chi River basin where HSB is located, but also to all other areas. He believes that Thailand is especially in need of policy research which will form a clear policy framework for water resource management and which should contain definitions of the RBO's responsibilities and allow for RBO participation. There is about one-third of the national population living in the Kong-Chi-Mun river basin areas, but the water resource administration is not well structured, with little RBO participation and without a clear mission.

Mrs. Ruenthong Pansaita

Position: Director

Organisation: Khon Kaen Agricultural Research and Development Centre

Mrs. Ruenthong thought that the project had engaged well with the food, energy and water nexus, and had managed to look at the relevant issues from many perspectives. She said that when only one organization works alone, the benefits and impacts are very narrow. However, when we get many organizations together, like in the project workshops, it creates a network, which helps broaden our view and better enables local participation. She sees the multi-sector approach as a successful way to implement planning and policy development. We believe she may have had these beliefs about multi-sector approaches before, but possibly had not had the chance to explore them until now.

Mrs. Benjamas Kodnongbua

Position: Regional Economy Team Executive

Organisation: Bank of Thailand Northeastern Region Office

Mrs. Benjamas now recognizes SEI as an important player in development research for Isaan and the GMS. She thinks that there are many different perspectives from many different sectors, but that these workshops have helped to completely align everyone's perspectives towards a sustainable development goal. She mentioned that the NGO perspective is that for development projects to be implemented, a strong supporting rationale is needed. She believes that if you have a strong rationale, you will have a successful development project, now and in the future.

Dir. Prasit Warnset

Position: Director of Secretariat Office of the Chi River Basin Committee

Organisation: Department of Water Resources Region 4

Dir. Prasit believes this project has encouraged the HSB Working Group to become invigorated in their roles. The working group now has better ways to exchange information and to create a clear picture of the river basin's development. In the past there were no mathematical models for the sub-river basin management, but now with the development of a model, we have some concrete information on the HSB basin that is more reliable as a basis for development decisions. He believes this type of information is also important for other basins, and methods should be extended outside HSB. However, Dir. Prasit thinks that mathematical modelling does not provide all the answers. He says it is just used to prepare information for locals so that they can reflect on their needs and make decisions about what they want to happen. He believes that the policy makers will benefit more directly from the results of this project than the local people because models are a key instrument of future policy planning for holistic development.

CHAPTER 8 List of Publications and Presentations

Bush, A., Krittasudthacheewa, C., Kemp-Benedict, E., Inmuong, Y., Seekuta1, P., Polpanich, O., 2011. Coupled modelling approach to scenario development for exploring climate change impacts. A conference paper presented to the 3rd International Conference on Public Health among Greater Mekong Sub-Regional Countries, 9-10 August 2011. Vientiane, Lao PDR. http://www.icphgms3.edu.la/The%203rd%20-%20Scientific%20Programs.htm.

Inmuong, Y., 2012. Creating Enabling Environment for Cross Sectoral Collaboration on Water-Food-Energy Nexus – Experiences from Thailand. Presentation made at Second Myanmar Green Economy Green Growth: Moving Forward. Nay Pyi Taw Forum, Myanmar International Convention Center, 13 to 15 November 2012.

Krittasudthacheewa, C., Polpanich, O., 2013. The Northeast Thailand Futures - The Nexus of Water, Food and Energy Investments. Abstract submitted to the Mekong Environmental Symposium, Ho Chi Minh City, Vietnam, 5-7 March 2013.

Krittasudthacheewa, C., Polpanich, O., Bush, A., Kemp-Benedict, E., (in preparation). Impact of Uncertain Future Climate and Development on Agricultural Water Management in Northeastern Thailand. Smakhtin, V., Johnston, R., Chu T., H.: Climate Change and Agricultural Water Management. CABI Climate Change Series.

Krittasudthacheewa, C., Polpanich, O., Pravalprukskul, P., 2013. Exploring the Nexus of Water, Food and Energy Investment in Thailand. Abstract submitted to the SEI Science Forum, Stockholm, Sweden, 13-14 February 2013.

Krittasudthacheewa, C., Polpanich, O., Pravalprukskul, P., Kemp-Benedict, E., Inmuong, Y., Bush, A., 2012. The Northeast Thailand Futures – Exploring the Nexus of Water, Food and Energy Investment. Abstract submitted to and presented at Second Myanmar Green Economy Green Growth: Moving Forward. Nay Pyi Taw Forum, Myanmar International Convention Center, 13 to 15 November 2012.

Polpanich, O., Krittasudthacheewa, C, 2012. Future Challenges in the Northeast Thailand: the Nexus of Energy, Water and Food Investments. Abstract submitted to and presented at the World Water Week, 26-31 August 2012, Stockholm, Sweden.

Annex 1 Stories about Future

Authors: Orn-uma Polpanich, Angela Bush, Phatcharee Seekuta, Chayanis Krittasudthacheewa

Final four stories about the future of HSB sub-basin have been jointly developed by the stakeholders who participated in the second scenario building workshop during 2-3 June 2011, and can be found below.

Story from Group One

A local sub-district chief, 40 years old, has two pieces of land. The first piece of land is about 10 rai (1.6 hectare) and the second is 100 rai (16 hectares). He has two children, the first born is named "Keng" ("accomplished") is a very good student. His father therefore supported him to study abroad until he finished his Master's degree. Keng is very knowledgeable, and an expert in WEAP and SWAT modelling programs, which can be used for local planning and management of water resources.

Keng asked his father for the 100 rai piece of land with the hope that in five years' time he could definitely make profit from this piece of land by growing sugar cane, a monoculture crop, because of its high price and ability to send to ethanol and sugar refineries. Keng imported modern machinery to support his production and used chemicals to improve his yields. His father therefore agreed to hand over the 100 rai of land, although the father personally believed in integrated farming following the self-sufficiency economy theory. After five years Keng was running a lucrative production, as he had hoped.

The younger son's name was "On" ("soft"). He was not a good student but liked farming. His father therefore let this son learn integrated farming following the self-sufficiency economy theory. The father specified a plan for integrated farming and water management. He emphasized the importance of maintaining water quality to optimize water use, as well as studying the state of wastewater from factories and agricultural chemicals, and studying water shortages. In addition, he taught On about rice farming, fish culture, growing medicinal plants, and short-lived garden vegetables. He taught On to plant different species of *Dipterocarpus* trees (e.g. *Shorea obtusa, Shorea siamensis*), which help create conditions for natural mushrooms to grow. He also taught On how to process different products to add value to them, considering the importance of the environment and avoiding chemicals. They planted more than 2,000 trees.

Five years later, water quality in the HSB basin declined. Fish in the streams died in large numbers because of the release of chemicals from lack of awareness by factories and community members, which affected everybody's livelihood in the community.

In addition, an economic downturn resulted in decreasing prices of sugarcane products. Keng lost money from not being able to sell his product at a favourable price. He fell into debt and his property was confiscated.

Keng returned to being dependent on his father. His father taught him integrated farming practices. Even though they were not rich, they could survive and take care of their family. Keng then understood that growing many plant species is more secure than dependence on one crop. He turned to mixed agriculture following self-sufficiency economy principles, such as fish culture and growing rotational crops such as plants in the legume family. He put excess material to good use; for example, he fed cattle with spare grass and used cattle dung as fertilizer. He also made wood vinegar, and liquid bio-fertilizer. These are examples of using raw materials to add the highest value and a way of reducing expenses, reducing use of industrial chemicals by turning to use animal manure and liquid bio-fertilizer.

From there, he started to produce bricks from lateritic soils. Keng applied the knowledge he accumulated from past experience. He used internet technology to help sell products, and to study product prices and world market prices. He also used different forms of modern technology.

His work included developing 'villager experts' for product development, including communication within and between villages. This was supported by the relevant government agency with community participation. He paid off all his debts within ten years' time.

While practicing diversified agriculture, Keng, On, and their father jointly established a centre of organic agricultural learning that combined academic knowledge, local knowledge from villager experts, and modern technology, aimed at transferring knowledge to local people interested in applying it in their agricultural practices. They grew mixed crops, for example cassava, with the expectation that their project would be successful in ten years' time. They also established groups or networks in the village, for example a women's group and a youth group, in order to be key components in planning, management, and monitoring water quality in the community, to avoid the problems that occurred in the past.

They also established a toxic chemical-free vegetable growing group in the area, with support from the state, until it developed into a large toxin-free vegetable growing area, which sold to a major department store in the province. And in thirty years from 2011, a water diversion scheme from Lao PDR to HSB was been finished, according to the Khong-Chi-Mun project, making the HSB basin the largest organic vegetable growing area in the country, exporting products worldwide.

Story from Group Two

In the next 30 years, HSB will be become more developed and urbanised. There will be a new main road built in front of through the entrance to this area, the so-called "East West Corridor", connecting Mae Sot (western Thailand) to Kwang Klee in Vietnam. Other roads will expand from four lanes to six lanes. The villages near the entrance to this place will experience growth and hence they will give this area a new name: "Phromnimit Villa."

The Khok Si Sub-District Administration Organization will be raised in status to a municipality. Because there will be more people living here, it will become an urban community. The Rajamangala University of Technology Isan will develop into an international university with 40,000 students. People from ASEAN neighbouring countries will come study here.

Communication will be 10G – the 10th generation. Economic, social, and political conditions will change due to an increase in economic prosperity, but the main paradigms and social drivers will still be capitalism, consumerism, and materialism (in some sections).

Mr. Dee is a-60 year old farmer in the HSB area who must adapt himself dramatically. He has 30 *rai* (about 4.8 ha) of land (in a good location). He decides to sell 25 *rai* of it to an industrial estate because they offered a good price. He also believes that the industrial estate would be a source of income for the local community. With that income he plans to send his son Mr. Den for higher level education and to return to be a community leader in the future. As for the remaining 5 *rai* (0.8 ha), Mr. Dee still practices organic farming because he sees that he is still able to sell to urban communities. He grows plants in structures where he can control temperature and humidity, and hires labour from neighbouring countries.

At the same time, the state has policies and standards related to supporting the environmental protection industry and organic farming.

Mr. Den graduated with a Masters of Public Administration from the National Institute of Development Administration (NIDA). His previous ambition was to return to become a community leader to develop his local place with the goal of developing the HSB basin to become an area with natural and environmental fertility, an area which can be used efficiently.

Mr. Den ran for election, and was elected to the position of President of the *Khu Kham* Sub-district Administrative Organization (SAO). He started to implement his vision, with the support of the SAO for his plans and projects. They built a rubber weir to store water in the dry season and also built temporary retention basins in places with chronic flooding.

He asked for cooperation of the community and relevant people to help look after these projects. They supported forest planting to sell carbon credits, organic agriculture, and eco-tourism. But in the beginning they experienced problems, especially water pollution, water management problems, because wastewater from industrial factories was not 100% under control. There were also conflicts over water between the industrial and agricultural sectors. Community cooperation and support from other sectors was still not great.

In the next five years, Den was still voted in as the President of the SAO. He was able to deliver projects to support and develop the HSB river basin as he hoped for, in an improved manner. At the same time state policies regarding environmental protection industries and organic agriculture became more concrete. Community meetings occurred. Common understanding was created at the local level and among all sectors to support the development of the HSB basin, so as to restore it to its original state. In the end the basin was increasingly restored in different aspects.

Ecotourism along the HSB river was managed. Water quality improved. Den together with the community supported the community in achieving self-sufficient livelihoods. The community grew plants organically for local-consumption. They helped each other preserve nature, and local customs and culture, such as the *Bang Fai* rocket festival which the community would organize in May every year.

The Khu Kham Sub-district changed from growing rice to growing sugar cane to supply to ethanol factories because the price of sugar cane improved. Mr. Den in his capacity as President of the SAO organized a project to support the growing of sugar cane, for example by establishing a Khu Kham United Sugar Cane Growers' Group, as well as homemakers' occupational groups, such as a wetland reed mat weaving group. These were means of creating income for the community. He also organized fertilizer credit cards and low interest loans for production. But in any case there were still problems with petty theft, which led the SAO to establish community policing to keep an eye on and take care of community living. This led to a better quality of life for the HSB community. Their physical and mental health improved as the larger society developed more fully.

Story from Group Three

In 2046, an old man with a granddaughter named Jintara changed from growing mainly sugar cane crops to rubber trees due to the high price of latex at 400 Baht/kg. Some other farmers also turned to grow more perennial trees. This resulted in a decrease in chemical use, and an increase in forested areas and water storage. Rubber plantations generated more income than other types of agricultural crops (annual cash crops) and had become more sustainable. In addition, latex collection could provide a continuous supply of cash every day before crop harvesting. However, global mean temperatures had continuously risen by about 0.5°C over that century. During that time the government developed a carbon credits trading system and policies that encouraged growers to sell credits on the carbon credit market. This system enabled rubber farmers to earn extra income, because rubber trees, with their large size, long lifetime and large leaf surface area, are very effective at capturing carbon.

The old grandfather had changed from growing sugar cane mono-crops to multi-cropping that combined the growing of rubber trees and other agricultural crops in a sustainable manner. His cultivation of rubber trees, rice paddies and sugar cane in his land area were 30 rai, 25 rai and 25 rai, respectively. As the trees were not fully ready for harvesting until the seventh year, the old man planted cassava intercropped with the rubber trees. He also became a member of a group of organic soil fertilizer users. In the meanwhile, he put some land aside to practice integrated farming (20 rai), which included different types of activities such as raising pigs and poultry, rice farming, and digging a farm pond for fish raising. The main branch of the HSB was the only water resource that flowed through his farm to supply water for farm activities. The integrated farming practices helped increase the income of Jintara's family. Despite having a far better financial position, her family had still chosen to adopt and practice the sufficiency economy philosophy. In the dry season, the grandfather was a leader of collective of people living in the neighbourhood and led projects to dredge the beds of particular unlined canals that had silted up, to maintain the weirs, and to build more irrigation canals to improve water availability for agriculture.

The grandfather successfully installed a drip irrigation system in his rubber plantation after learning from the YouTube internet website. He had access to the 'web by that stage because the entire country used wireless internet services. As sufficient water was provided by the irrigation system, it increased latex production in the rubber trees and extended the period of latex tapping. Although there was a variety of farm activities, only his son and daughter-in-law were the main labour force for the household. The little girl Jintara was just a child and she could not significantly help working in her grandfather's farm lands. As a result, the grandfather had to hire some migrant farm workers, who mainly came from neighbouring countries in the Mekong region. Due to advances in national medical care and the public health system, there had been an increase in the life expectancy of the HSB people and the population gradually grew older. In contrast, over the following decades, the birth rate increased steadily by 1% per year.

As time passed, and Jintara reached 19 years of age, a Trans-Asian high-speed rail network emerged and grew. China had played a leading role in economic growth, food science and other various fields. The old man therefore decided to send Jintara to study modern agricultural science at the University of Guangzhou, China. Over time, China built dams on the Mekong River's tributaries in order to serve power production in the nation. Since the river flows through a number of countries, the building of dams resulted in changes to the river's ecology and biodiversity. In addition to changing ecology and hydrology, dam construction also indirectly contributed to climate change through deforestation, and this was a leading cause of aquatic species loss. Also as a result of dam construction, agricultural areas were diminished due to the lower water level of the Mekong River. The consequent effect on Thai agriculture was higher production costs and living expenses. Farmers needed to quickly sell their products to meet the increased market demand. These were the important factors that led to the farmers increasing their use of agricultural chemicals.

Jintara completed her undergraduate and graduate degrees successfully. While studying, she had fallen in love with a young Chinese man. Upon graduation, they decided to get married and had one child. They engaged in a business in China, and it grew to be a well-reputed agribusiness.

Fifteen years later, in 2061, Jintara and her family returned home to HSB and her Grandfather decided to give her all of his land. The location of the land was very good, so naturally a land broker came to try to convince her to sell the land. He offered very high prices, about 10 times more than the market value. Even so, Jintara did not sell because she felt responsible for the legacy of her grandfather's land which she alone had inherited. Together with seeking a potential business opportunities in Thailand, Jintara then build a rubber processing factory in Kranuan District, where her land was located. Her factory was in a good position to buy rubber products from the Mekong Region countries. Under the new transboundary trade agreements, her business was exempt from import tax for the first eight years of operation, therefore, she could benefit extensively from the regional trade agreement. Goods produced from her factory were mostly exported for sale on the European market. Her business went very well, with good profits, and ensured her growing financial stability.

Due to her better financial status, Jintara had contributed funds to do research in promoting rubber plantation in HSB. The research funds were allocated to the Rajamangala University of Technology Isan Khon Kaen Campus (KKCRMUTI) and led to the development of a latex-rubber tapping machine with automatic warning system. The new machine helped farmers reduce the labour costs for rubber tapping in the HSB area. The university also provided farmers with knowledge for managing rubber plantations to meet sustainable farming practices, such as by reducing the use of chemicals and increasing effective use of water resources.

Story from Group Four

In 2011, a woman had one grandchild named Ah Pao. He was the second child of Nathan, the woman's son. Ah Pao studied in the Faculty of Agriculture, Khon Kaen University. His grandmother thought that he could well help the family on the farm in the future. In the following 30 years, due to the extensive development in the HSB, the main transportation road through the area was upgraded from 4 lanes to 6. Nevertheless, integrated farming practices had not been greatly adopted by many farmers in the region.

Despite this, Ah Pao was particularly interested in integrated farming and began to practice it. The combination of agricultural crops he planted was: root crops such as galangal and lemon grass; vascular plants such as chillies, eggplant, squash and melon; fruit trees such as papaya, jackfruit, and others; and long-lived trees for the younger generation to harvest such as teak, dipterocapus, and *Toona ciliata*. Ah Pao asked his grandmother to help him apply for a loan from the Bank of Agriculture (BAAC), in order to purchase 10 rai of land which his father had sold earlier. He divided the 10 rai of land into two parts: about 70% of the land was for growing economic crops of rice, cassava and sugar cane and the rest he used to do integrated farming activities such as fish raising in ponds, raising poultry, and growing the fruit trees, perennial trees and vegetables already mentioned. Chemical fertilizers were not used on the integrated farm; only organic fertilizers were applied instead. His organic farm was successful and was a good example to others, and his organic farming group had now engaged more members. Many initiatives in the community were established and started implementing group activities, such as organic farming practices, organic liquid manure production, pellet organic fertilizer production and green manure production. The purpose of these groups was to reduce chemical fertilizer use and increase the use of organic fertilizers instead. The produce from these organic farming practices were mainly consumed by the household. If there was any excess produce, it was sold in the neighbouring markets. Materials used in organic fertilizer production were mostly derived from household waste, animal manure, organic waste, and plants available in the area. Through these changes, everybody was able to eat clean food which helped in the development of good health. Eventually, it was possible for the organic produce from the HSB area to be commercially exported to external markets.

By 2021, Ah Pao was a successful farmer and a fine example to others. He presented his success in organic farming practices to others in the community. The fellow farmers had generally adopted organic farming, but some still used chemical fertilizers. Ah Pao was appointed as a chairman of the HSB community board, aimed at developing the strengths of the community. The developments he ushered in during his term as chairman included participatory water resource management, carbon trading, human development activities and increased adoption of organic farming practice. In addition, people in the local community began to improve certain facilities in the community. The first improvement was constructing check dams to break the flow of water; they were built completely through the cooperation between the villagers. The dams also allowed the water to seep into the soil. In the long term, this encouraged fertile soils and healthy forests in the area which were suitable for organic farming, which allowed the conservation of beneficial insects. The community group also set up a carbon emissions reduction fund and increased awareness of natural resource dependency. Ah Pao was the leader of an initiative to increase forested areas and utilization of forest resources, as well as a monitoring program of community health. The monitoring showed that the people were in good health and it was generally a model community.

Annie was Ah Pao's elder sister. As a teenager, she was not interested in fashion and her father taught her about saving since childhood. Through her upbringing, she had long had her mind set on saving money. The HSB community had encouraged the local youth to preserve local traditional wisdom. Even though Annie did enjoy using the internet and other modern technology, as most young people did, she was a conscientious girl who had never destroyed her own dignity or that of her family. The Tambon Administration Organization (TAO; the most local level of government in Thailand) provided records of the traditional knowledge to the local community people. Ah Pao later established a Learning Centre in the community. Fortunately, Annie had been trained in the development of labour skills in the centre. Hence, Annie had become a key player in helping to train the local people in the community. She used the internet technology to assist in the training.

By 2041, the Learning Centre had developed over the years and had strengthened its capacity significantly in providing and recording local traditional knowledge. The centre had now been inherited by the children of Ah Pao and Annie. They followed in their parents' footsteps and aimed to help the HSB community to become an important centre for community learning at both national and international levels. The Learning Centre was divided into four departments as follows:

1. The HSB Organic farming group. This was a group with extensive experience in organic farming, consisting of experts who would disseminate information about producing organic fertilizers, liquid organic fertilizer, pellet organic fertilizer and green manure.

2. The HSB Marketing group. The group supplied information on self-operated marketing processes and implementation.

3. The HSB Agro-Eco Tourism Group. This group was designed to support the sustainable management of community-based forest and to protect nature. The villagers would use the natural assets of a farm and its surroundings to give visitors the opportunity for agri-education as well as eco-tourism. This group aimed to show visitors how natural resources were more like a supermarket to the local community people as they knew how to utilise them properly.

4. The HSB environmental group. This group operated as it always had since before 2011.

Annex 2 Review of Relevant Policies and Major Development Projects in NE-Thailand

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The different water management visions of different government and NGO stakeholders have resulted in a lack of clarity regarding water management. Many government agencies, such as RID, DWR, and NESDB, have illustrated Northeast Thailand or Isaan as very dry and drought-stricken, as well as very poor. The national water vision mentioned that the Northeastern and Central plains experience frequent droughts and floods, due to increasing water demand and deforestation (Setthaputra et.al, 2001). The government attempted to increase water resources and divert water from international rivers such as the Mekong river, and from neighbouring countries such as Lao PDR and Cambodia, to increase water for agriculture, industrial, and tourism in Northeast Thailand. Increasing of national electricity demand and water led to hydropower development projects e.g. the Pak Mun dam. It was clearly understood that the geography of Northeastern Thailand is unsuitable for large-scale water storage or water development projects, due to high investment costs and geographic and environmental constraints (Setthaputra et.al, 2001; Ardwichai *et al*., 2005; TDRI, 2010; Sorsai, 2010; Living River Siam, 2011). Consequences from water development project in Northeast Thailand have included wetlands and aquatic diversity loss, and salinization, which are considered environmental critical problems (Floch, 2007; Blake and Pitakthepsombat, 2006).

National Water Policy

TDRI (1990) distinguished water management in Thailand into three main periods. The first period (1283 - 1857) was relocating people to areas suitable for agriculture with sufficient water, and away from flood-prone areas. The second period (1857 - 1990) emphasized supply-side management, which was to increase water resources and water regulation for agriculture and transportation. During this period, irrigation and drainage were the main components of management. And the last period (1990 – 2025) emphasized demand-side management by control and regulation of wastewater and water conservation, due to population and economic development pressures. Water rights and allocation plans were set up to minimize and mediate conflicts during this period (Setthaputra *et al.*, 2001). The concept of participation in natural resources and environmental management (soil, water, forest, fishery, waste, etc.) has been strongly advocated since the late 1990s with the introduction of the new constitution in 1997 and the 8th National Economic and Social Development Plan (1997 – 2001) (Kajina, 2008; Floch and Blake, 2011). In 2001, the national water vision statement for Thailand explained the need for sufficient water, water quality and stakeholder participation in water management (Sethaputra *et al.*, 2001).

Currently, there is no long-term national water resources management plan, and no targets have been set for the various agencies to follow. Despite the vast authority given to it under the Prime

Minister's Office regulation of 1989, the National Water Resources Committee (NWRC) functions like an ad-hoc committee, tackling immediate and short-term problems. So far, government set the priority to increase water supply/volume from intensive investment in several mega projects. The previous national water management policy (2004 – 2008) emphasized dam and reservoir development, and water diversion projects (Inmuong, 2008).

Water policy mainly responded to demand for agriculture activities, household consumption, and industry, respectively (Inmuong, 2008). Improving water resource management required empowering local people to participate and use existing local knowledge in managing their water resources, as well as extend good practices in small-scale water management, particularly in non-irrigation system areas (TDRI, 2010). Thailand has begun using river basin based water resources development and management systems since 2002 by dividing the country into 25 river basins (MRC, 2004). The management of Water Resources of Thailand has been organized at two levels, including national and river basin levels. The IWRM concept has been introduced to improve water resources management, and it was also established as the officially sanctioned water management paradigm (Floch and Blake, 2011).

Water Resources Development Project in Northeast Thailand

The goal of water resources management in Northeast Thailand is similar to that of water management and governance in Mekong River: water for the expansion of irrigated agriculture and industry, hydropower generation, fisheries, and control of annual floods (Sneddon and Fox, 2006). Water resource developments in Northeast Thailand mostly invested in the main river systems, including the Mun, Chi and Songkhram river basins (Molle *et al.*, 2010). The concept to divert water from Thailand's neighbouring countries such as Lao PDR and Myanmar has been regularly repeated after it was first proposed in the KCM project. For example, the former Prime Minister Samak Sundaravej proposed two river diversion plans. The first plan was to divert water from the Mae Yuam River, which is next to the Salween River, to Mae Hong Son province to be stored at the Buhmibhol dam in Tak province. The second plan was to divert water from the Nam Ngum River to Lam Pao dam in Udonthani province (Winwong, 2008). The five major water resources development projects are described below.

Green Isaan or "Isaan Kiew" project (1987)

In 1987, Army Commander-in-Chief General Chavalit Yongchaiyudh presented his majesty the king with a master plan for the development of the Northeast Thailand called Green Isaan or Issan Kiew (Molle and Floch, 2008). This project aimed to improve and develop agriculture land, water resources, and irrigation systems in the Northeast Thailand with support from the Royal Thai Army and related government agencies (Molle *et al.*, 2010). This project was introduced and promoted to support rubber plantations in Northeast Thailand in 1989. The plantations had expanded to 5 million rai in 2012 (Office of the Rubber Replanting Aid Fund, 2012).

Kong-Chi-Mun project (1991)

The KCM project was proposed to the government since the late 1980s. This project received a boost from prime minister general Chatichai Choonhavan, who declared intentions "to turn the battle fields to marketplaces". This intention led development policy and plans for Northeast Thailand (Molle *et al.*, 2010). The Department for Energy Development and Promotion (DEDP) undertook large- and small-scale electricity pumping station construction in the Chi and Mun river basins. Rasi Salai Dam and Huana Dam were constructed under this project. The KCM project also proposed to divert water from Nam Ngum in Lao PDR to Thailand. The implement of the KCM project was protested from the local population, and created land disputes and salinization impacts (Floch and Blake, 2011; Molle *et al.*, 2010). The National Economic and Social Advisory Council (NESAC) commented to the KCM project that this project was not suitable for floodplains and the geography of Isaan, which cannot allocate water as mentioned in the project plan, and that it created environment and economic problems over the 13 years of implementation in phase 1 to improve small-scale water development in the Chi and Mun rivers (NESAC, 2009; RID, 2008). Public participation is needed, as are further conduct feasibility and environmental impact assessment studies in each constructed reservoir, especially Rasi Salai dam, more studies of flooding and salinity problems, preservation of flooded forests, as well as improvement of ecosystems in project implementation.

Pak Mun Dam construction

The Pak Mun dam was official approved by the cabinet in 1989 with inappropriate study on livelihood impact and public participation. This project was initiated by EGAT as part of EGAT's power development plan, which was not part of the Kong-Chi-Mun project (Molle and Floch, 2008; Foran, 2004). The Pak Mun Dam project proposed to generate hydro-electricity to meet increasing electricity demands and water demand for agriculture (Santiwutthimetee, 2000). However, this project has created large impacts similar to the KCM, such as salinization that affects local livelihoods, especially fishery. Movement against the Pak Mun dam management has been one of the longest movements in the history of Thailand. Pak Mun dam has been studied in many aspects. The major findings of the study are a lack of participation of local people in decision-making processes, lack of transparency and distorted information in environmental impact assessments (EIA) on fish and livelihoods based on fisheries, and in information sharing to local people (Thanapornpan, 1991; World Commission on Dams, 2000; Mun's Flooded Forest Conservation Committee, 2008).

Water grid project (2003)

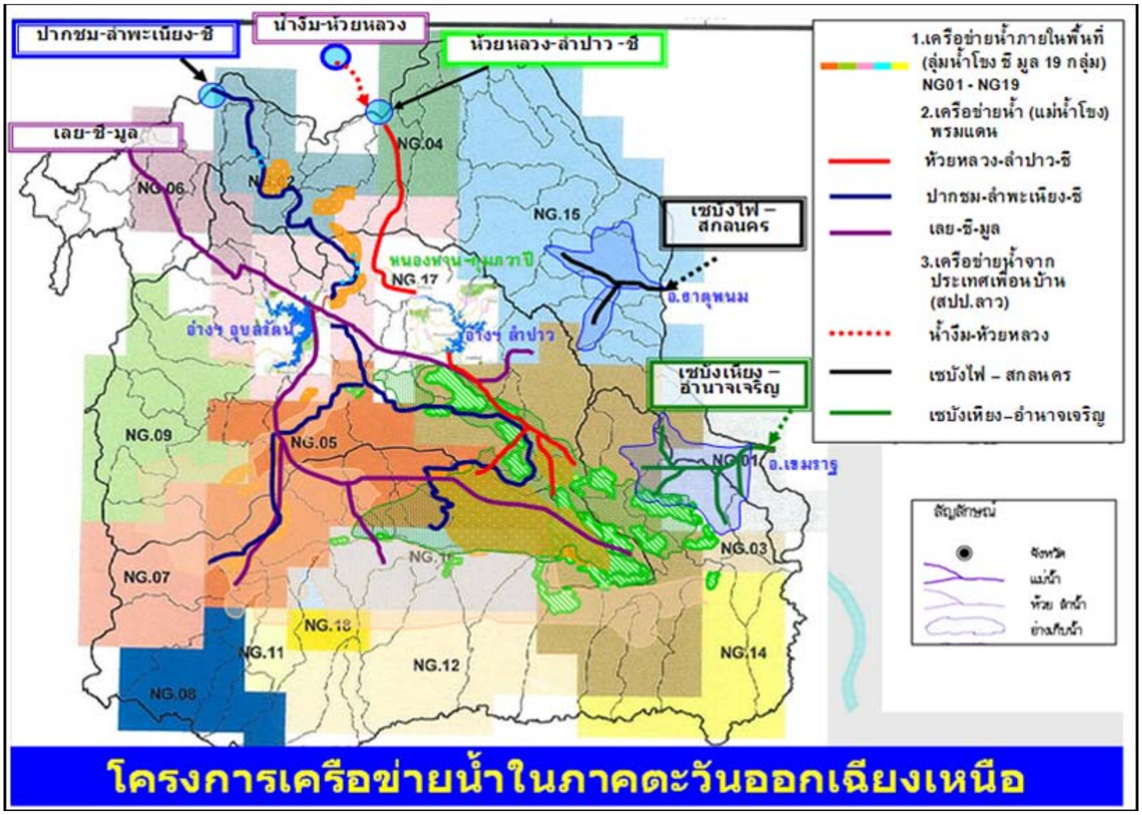
The water grid project was a following project to divert water from Nam Ngum that was initiated in the KCM project. It envisioned the development of an additional 60 million rai of irrigated land over a period of 23 years. This project focuses on 6 basins, including Nam Ngum and Se Bangfai basins in Laos and Huai Luang, Songkham, Mun and Chi basins in Thailand (Floch, 2007). This project extended the possible river diversions from Laos, and not only Nam Ngum. The Xe Bang Fai diversion was proposed to transfer water from Xe Bang Fai across the Mekong to Sakhon Nakhon to cover around 650,000 rai, and the Xe Bang Hiang to Amnat Charoen transfer another 2.5 million rai (Floch, 2007; Floch and Blake, 2011).

Kong-Loei-Chi- Mun project (2008)

The Royal Irrigation Department (RID) was transferred the completed project in phase 1 (improvement of small-scale water development in Chi and Mun rivers) of the KCM project from the Department for Energy Development and Promotion (former the NEA). This project plans to transfer water from the Mekong River to the Loei River in Chiangkarn district and Ubonrat dam for irrigated agriculture and water supply in Northeast Thailand (Living River Siam, 2011). In response to the infeasibility of KCM phase 2 and 3 pumping water from Mekong river to Huay Luang, Nongkhai province and pumping water across mountain areas to Chi and Mun rivers, the Kong-Loei-Chi-Mun project transfers waters through water tunnels with gravity to increase water by 50,000 MCM to cover a total of 21.9 million rai in Northeast region (RID, 2008). This project will take around 30 – 40 years for construction, which includes water tunnels and reservoirs (Trinate, n.d.). The project has conducted a project study with for a total of 720 days (September 2009 - 2011). A Strategic Environmental Assessment (SEA) was conducted for 240 days of study to inform project details and water development options, while the remaining 480 days were used to conduct the Feasibility Study (FS), Environmental Impact Assessment (EIA), Health Impact Assessment (HIA), and Social Impact Assessment (SIA) in selected potential gravity and pumping system sites. This was to explain the networking and water transfer method (gravity and pumping), water development and investment plans, and water management organization (RID, 2008).

Water grid network in 19 critical areas project (2010)

The water grid network in 19 critical areas project is a recent project, which was initiated by the Department of Water Resources, Ministry of Natural Resources and Environment. It is not only an internal water diversion project such as the Kok-Ing-Yom-Nan water development project in the north, but also a transboundary water diversion project from Laos and Cambodia like the Kong-Chi-Mun project in Northeast Thailand. During 2010 – 2012, this project is conducting the SEA studies in 3 major river basins in Northeast Thailand including the Kong-Isaan, Chi, and Mun river basins, as well as other studies such as FS, EIA, SIA, HIA, in 19 critical areas including Huay Nam Som, Huay Nam Mong, Huay Nam Suay, Huay Luang, Lam Panieng, Upper Ubonrat dam, Nam Chern-Nam Prom, Lower Ubonrat dam (on left), Lower Ubonrat dam (on right), Upper Lampao, Huay Saibat, Lampao (on right), Lampao (on left), Upper Songkram, Mid-Songkram, Lower Songkram, Nam Yam, Nam Oon, and the Mekong river. The project covers 167,355.96 sq. km within 20 provinces in Northeast Thailand. It aims to create equitable water use for all sectors, added water value, increased water supply and resources, water for agriculture, industry and tourism, as well as land-use planning for agriculture (DWR, 2011).



Source: http://www.dwr.go.th/prapa/network_water.htm

References

Blake D.J.H. and Pitakthepsombat R. 2006. Situation Analysis: Lower Songkham River Basin, Thailand. Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme, Bangkok Thailand . 121 pp.

DWR. 2011. "SEA Project's Site Information". Water grid network in 19 critical areas project, Department of Water Resources. Available: http://www.thaiwatergrid.com/information/index.php (in Thai).

Floch P. 2007. "The Thai-Lao Water Transfer: Proposing Land and Water Resources Development the Large Way". M-Power Research Update 16, March 2007.

Floch P. and Blake D.J.H. 2011. "Water Transfer Planning in Northeast Thailand: Rhetoric and Practice". In Lazarus K.; Badenoch N.; Dao N. and Resurreccion B.P. (eds), Water Rights and Social Justice in the Mekong Region, pp. 19 – 38. London: Earthscan.

Inmuang Y. 2008. Rethinking for the Current National Water Policy. Available: http://wwwoknation.net/blog/print.php?id=340183 (in Thai).

Kanjina S. 2008. "Participatory Water Resource Management in Thailand: Where are the Local Communities?". IASC Conference 2008. Available: http://iasc2008.glos.ac.uk/conference%20papers/papers/K/Kanjina_155201.pdf

Living River Siam. 2011. Mekong – Loei – Chi – Mun Water Transfer Project. Available: http://www.livingriversiam.org/mk/mek_a22.pdf (in Thai).

Molle, F.; Floch, P.; Promphaking, B. and Blake, D.J.H. 2010. "Greening Isaan": Politics, Ideology, and Irrigation Development in Northeast Thailand. In Molle, F.; Foran, T. and Käkönen, M. (eds), Contested Waterscapes in the Mekong Region: Hydropower, Livelihoods and Governance, pp. 253-282. London: Earthscan.

Molle F. and Floch P. 2008. Water, Poverty and Governance of Megaprojects: The Thai "Water Grid". Working Paper. AMBIO, vol. 37, no. 3, pp 199 – 204.

MRC. 2004. "Thailand River Basin Planning and Management Structure". Consultant Report on Training and Capacity Support Needs of Thai River Basin Organizations Involved in the Mekong River Basin Development Plan. Available: http://www.tnmckc.org/upload/document/bdp/4/4.2/5%20Module%204%20Applying%20Principles/Handout%204.4%20thailand%20RB%20structure.doc

Mun's Flooded Forest Conservation Committee. 2008. "Voice of Vulnerable People: Pak Mun Dam". Centre for Peace and Human Right of Issan Thailand. Available: http://globalgrassroots.files.wordpress.com/2011/02/pak-mun-report-ciee-thai-smallfile.pdf (in Thai).

NESAC. 2009. Comment and Suggestion of NESAC for Kong-Chi-Mun and Water Management in Northeast Thailand. Available: http://www.tdri.or.th/download/reform/4_water/2009-06-23_khong_si_moon.pdf (in Thai).

Office of the Rubber Replanting Aid Fund. 2012. ORRAF News. vol. 46/2555 (in Thai).

RID. 2008. "Khong – Loei – Chee – Mun Project Background". Khong – Loei – Chee – Mun Water Management Project. Available: http://www.khongloeicheemun.com/become.html (in Thai).

Santiwutthimetee W. 2000. "10 Years Pak Mun Dam: A Fighting of Poor and Rebel People". Sarakadee Magazine, vol 06. Available: http://www.sarakadee.com/feature/2000/06/dam.htm (in Thai).

Sethaputra S.; Thanopanuwat S.; Kumpa L. and Pattanee S. 2001. "Thailand's Water Vision: A Case Study". From Vision to Action: A Synthesis of Experiences in Southeast Asia. Available: http://www.fao.org/DOCREP/004/AB776E/AB776E00.HTM.

Sneddon C. and Fox C. 2006. "Rethinking Transboundary Waters: A Critical Hydropolitics of the Mekong Basin". Political Geography, vol. 25, pp 181 – 202.

Sorsai P. 2010. Kong – Loei – Chi – Mun Water Management Project and Fraud SEA. Available: http://www.greenworld.or.th/greenworld/population/760 (in Thai).

TDRI. 2010. Policy Recommendation to Government on Water Resources Management. Available: http://www.tdri.or.th/download/reform/4_water/2010-12-08_policy.pdf (in Thai).

Thanapornpan R. 1991. "Lesson learn from Pak Mun Dam Project". In From Tha Prachan to Sanamluang, Manager magazine, 20th December 1991. Available: http://econ.tu.ac.th/archan/rangsun/บทเรียนจากโครงการเขื่อนปากมูล.pdf (in Thai).

Trinate K. no year. Kong – Loei – Chi – Mun Water Management Project. Available: http://kmcenter.rid.go.th/kcsurvey/pdf/New%20PDF/khongcheemoonloe.pdf (in Thai).

Wingwong K. 2008. Thailand's River Diversion Plans for Whose Benefit?. The Irrawaddy (Newsmekong). Available: http://www.irrawaddy.org/highlight.php?art_id=13687.

World Commission on Dams. 2000. Case Study Thailand: Pak Mun Dam and Mekong/Mun River Basins. Available: http://geocompendium.grid.unep.ch/reference_scheme/final_version/GEO/Geo-2-054.htm