# A Decision Support Framework for Catchment Based Natural Resource Management

**K. Saifuk**[a] **and S. Ongsomwang**[b]

[a]Land Development Department, Bangkok, Thailand (kamron@ldd.go.th)

[b]Royal Forest Department, Bangkok, Thailand

Natural resources management in Thailand requires consideration of the trade-off related to social, economic and environmental outcomes of resource use decisions. This type of decision making also requires coordination of various government agencies engaged in areas associated with the management of these resources. This paper describes the decision support framework being developed as a part of the second phase of the IWRAM project. This project involves the coordination and collaboration of a wide range of government agencies in the development and application of a decision support framework, with teams of researchers working both in Thailand and Australia. The decision support framework considers issues such as the impact of deforestation on streamflow, erosion and household income and subsistence production. This allows the trade-off relating to various management scenarios to be considered. The framework further develops concepts arising from Stage 1 of the IWRAM project, in such as way as to allow the decision support tool to be used by extension officers of key agencies in Thailand.

***Keywords:*** *Decision Support System; Water resource management; Thailand*

## 1. INTRODUCTION

Thailand is dominated by tropical rainfall and climate. About 30 percent of the country is mountainous. The country can be divided into 25 main basins, which can be subdivided into 255 sub-basins. The Northern region of Thailand contains the most important watershed area. This watershed occupies 50.95 percent of the region and 16.84 of the whole country. The most important river of Thailand is the Chao Phraya, which comprises four tributaries the Ping, Wang, Yom, and Nan rivers running from North to South. These pass through the central plain to a huge flood plain. These contain the most fertile and productive rice fields.

In the past, water resources in Thailand have been surplus to demand and have strongly influenced the lifestyle of the Thai people. The people settled along sides of the rivers growing rice, vegetables, and fruit trees as well as fishing. The rivers are also very important for transportation, trade and communication.

Currently, the increasing population means that forest areas and watershed lands are being encroached by agriculture and infrastructure constructions such as roads, dams, reservoirs, and mining. Logging concession was also practiced at large scale before 1988). Decreasing forest cover is a key underlying problem, causing irregularity of rainfall, flooding hazards in the rainy season and drought in some periods of the growing season. Flooding and drought have been more significant in recent years. Management of the headwaters and watershed are vital, but the complexity of watershed components is great, with cause and effect interlinked. The fundamental issue is to develop high productivity and carrying capacity of the catchment or watershed whilst achieving acceptable environmental quality and protection of the land and water resources.

IWRAM-DSS is a decision support system for integrated water resource and management. It is a tool that has been developed for predicting productivity and biophysical impacts of a range of management scenarios

### 1.1. Background of the Case Study

The Ping, Wang, Yom, and Nan are the four tributaries of the Chao Phraya River, the most important river of Thailand. The four tributaries originate in the northern mountainous areas and run through the main cities of Chaingmai, Chinaware, Lampang, Tak, Phrae, Nan, Kampangphet, Sukhothai, Pitsanulok, Pichit provinces. The tributaries meet at Nakhonsawan province and are then named the Chao Phraya (the great river). The river then runs through the Chao Phraya flood plain, the rice bowl of Thailand, via Ayutthaya the old capital and Bangkok, before flowing down to the Gulf of Thailand. The length of Chao Phraya is about 300 kilometres (from Nakhonsawan to the sea); the lengths of tributaries are between 300 - 400 kilometers.

The watershed areas of the Ping, Wang, Yom, and Nan are rapidly being encroached by agricultural activities. These activities include field crops such as maize and up-land rice with traditional practices. Slash and burn is the first step of this system. This is followed by shifting cultivation after continued cropping for some years. Declining yields have occurred as well as soil erosion. The soils have become poor, with reduced percolation while water run-off and soil erosion have increased. Water resource management is directly related to cropping patterns and domestic consumption. The water resource in the top of the catchment acts as a supply for crops and people there, as well as to the lower areas of the catchment. The impacts from land use activities are found both on-site and off-site Soil erosion has reduced the soil fertility of arable land and sediments have accumulated and filled-up the streams in the low land giving rise to a shortage of water in these areas.

Water shortage and flood hazard have become common and significant events. In order to prevent these disasters, integrated water resource management is needed to plan land use scenarios for the catchment which sustain incomes and maintain the environment and ecosystems.

### 1.2. Objectives

The development of IWRAM-DSS aims to achieve five main objectives:

- to provide a common tool for agencies concerned with water resource management;
- to evaluate the productivity and impacts of the catchment;
- to investigate situations of land use change and land conversion that might happen in the catchment;
- to optimize land use activities according to the needs and opportunities of the community;
- to prioritize and address the problems that should be managed and overcome; and,
- to recommend alternatives crops and management practices for sustainable land management and income sustainability.

## 2. APPROACH

Four main components of the catchment are forest and land cover, landscape, climate and rainfall, and people. These components have to be understood and managed both from individual disciplinary viewpoints and also as integrated scenarios on the basic backgrounds of supply, demand, and impacts. Four modules or compartments are formulated to evaluate the supply, demand, productivity, and biophysical condition of the catchment. The outputs and information from these modules are provided in the core module (IWRAM-DSS Core Module). The IWRAM-DSS components are:

- Hydrology Module - estimates grid based rainfall-runoff values using a modified SCS curve number approach;
- Crop Module - calculates crop yield and water use for each crop and land unit combination;
- Soil Erosion Module - calculates erosion under various land use and management scenarios using a modified USLE approach (see Merritt et al., 1999);
- Socio-Economic Module - estimates land use decisions and income effects under varying input assumptions using a decision tree approach.
- IWRAM-DSS Core Module - integrates outputs from different component modules, and creates spatial and temporal outputs which can be investigated through the DSS.

## 3. CONFIGURATION

The modules are designed to allow modification of inputs and to display outputs as maps or in digital formats. Four concepts have underlaid the IWRAM-DSS design.

- to be an open-based system;
- to allow spatial analysis and display;
- to be capable of being modified and applied in different catchments and environments; and,
- each module is stand alone, but uses and shares the required data sets

## 4. ASSESSMENT

At the end of the first phase of the project, the configuration of the DSS (Letcher et al., 2002) relied upon the concept of land holding of paddy or upland. The primary unit of analysis was the Resource Management Unit (RMU), which is a classification of households on the basis of access to paddy and/or upland fields (see Letcher et al., 2002; Scoccimarro et al., 1999). Thus the RMUs were not unique in soil characteristics and land qualities, such that different RMUs had the same soil type. This ambiguity created difficulties in biophysical modeling specifically in the erosion module, crop module, and the hydrological module and even for aspects of the socio-economic module, for which the concept of the RMU as the unit for land use planning / zoning was proposed. The other constraint was that RMU- based model output was not able to be mapped in the detail required by extension officers.. This provided difficulties when extending model results to specific on-ground management works. However, the outcomes of phase I still provided significant knowledge for the development of single modules such as the soil erosion module, crop module, and hydrological module and on strategies for integrating separate components. From phase I, we learned that **the economic linear programming** model and RMU- based model were not appropriate where the outputs are required on a highly disaggregated basis.

In order to solve these problems, phase II was conceptually designed to use the GIS- based or spatial data to represent the land and land use attributes, involved in the IWRAM-DSS development**.** There are many key workers **and stakeholders** that will be used among our working group from various agencies. These include the Royal Forest Department, Royal Irrigation Department, Department of Agriculture, Royal Project Foundation, Chiangmai University, Land Development Department, etc. These workers are volunteers and are the main target of our users when phase II of the project is finished. After that it is envisaged that the IWRAM-DSS will continue to be used and applied at a Nation wide scale.

**Land Unit (LU):** A Land unit is defined using the FAO Land Evaluation definition (FAO, 1976), as an area with homogeneous land qualities influencing crop performance, and with the same management and practices.

**Land Utilization Type (LUT):** Land utilization type is defined land uses at both macro and micro scales such as forest land, agricultural land, range land, pasture, field crops, fruit trees, rice, maize, and also with the more detailed attributes including variety and management level and the objectives of selling the products. In this study LUT will represent type of crop / crop variety and management level or practices, for example maize / medium rate of fertilizers/ contour farming, or Suwan 1 (maize variety)/ medium rate of fertilizers/ contour farming, etc. LUT's are land utilization types that have opportunities in terms of biophysical or socio-economic support and seem to be the promising crops to recommend or introduce in these areas.

**Present Land use:** This is defined from the result of a land use survey or interpretation, comprising both major kinds of land uses and more specific information on the type of crops and management. Present land use is the starting point of land evaluation, used to estimate the impacts and productivity of the existing land use conditions. Recommendations for changing land uses (LUT's) are applied to individual land units or households while land use scenarios consider promising land uses over the whole project area. Land use scenarios involve many options but demand and supply must be considered for a land use alternative to be developed on a sustainable land use basis. This principal is very important and Land use planners have to bear this in mind during planning.

**Land Modeling Unit (LMU):** A Land modeling unit is results from the intersection of Land Units with land use (scenario) areas. The Land Unit map does not change whereas the land use map changes according to land-use scenarios. Thus every land-use scenario when overlaid with a LU map will produce a new set of LMUs (polygons). So, when we change a land-use scenario, LMUs are also changed. An LMU is homogeneous in land qualities (attributes of Land Unit) and land use (crop). This is the unique unit that can used as the base unit for an evaluation and prediction from compartment modules such as the erosion module, crop module, and socio-economic module. The **LMU** will replace the concept of the **RMU** developed in phase I. The LMU approach is the fundamental key to allowing a GIS interface and spatial data analysis. Biophysical impacts and the productivity of land uses and land use scenarios are also able to be quantified and represented using maps.

## 5. PROJECT IMPLEMENTATION

Future work involved in developing and applying the IWRAM-DSS to new catchments in northern Thailand includes collecting basic data such as on soil, climate, land use, irrigation, socio-economics, crop requirements, etc. The main task is to assess the LMU of the catchment for use in the compartment modules. The steps in the IWRAM-DSS development are:

1. Land unit assessment according to land suitability of crops and land utilization types. The procedure to obtain LU is to overlay soil map with climatic maps (rainfall, temperature, etc.). So LUs are the land evaluation units for suitability assessment.

2. Prepare land use map / land use scenarios for three conditions:
   a) Existing land uses condition: This stage is the benchmark of further land use improvements, both land utilization types and land management. Land evaluation of the catchment is needed to evaluate the situation of impacts and productivity.
   b) The ideal land use scenario: Crops and management are interactively set to estimate the biophysically best option for each LU. The optimum land use scenario: This is a viable land use scenario that can achieve sustained yields and income. This scenario can change due to fluctuations in the cost of production, crop price, and marketing, etc.
3. Land Modeling Assessment: The LU map is overlaid with land use scenario maps. Each land use scenario creates one set of LMU's. So the three land use scenarios will provide three different sets of LMU's.
4. Evaluate soil erosion for each LMU of each LMU set.
5. Optimize crops (LUT's) and conservation practices in order to pass the threshold limit of acceptable soil erosion rate that had been set (National Standard is 2 ton/rai/year or 12.5 ton/hectare/year). This step is performed on the spreadsheet platform.
6. Link the outputs of step 2 to the GIS interface for spatial analysis and to allow production of output maps.
7. The land use / land cover map that contains attribute data of LMUs are shared with the component modules: the hydrological model, crop model, and also socio-economic model.
8. Execution of the compartment modules.
9. The outputs of each module are summarized in the IWRAM-DSS core module.

Four sub-basins of Chaingmai province have been selected as the study sites. All of the basic data such as soil, land uses, climatic data, socio-economics of villages and households, etc has been collected for these sub-basins. However, data required for the hydrological module and crop module need validation before the models are calibrated. Small micro-scale catchments have been selected for validation of the hydrological and crop models. The calibration of the soil moisture and water balance is currently underway.

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Even though the hydrological and crop models still require calibration and integration in the system, the IWRAM-DSS core module has already been designed using a spreadsheet, allowing optimization of LMU considering crop, practice, and farmer demand. The final integration will link the GIS platform with the IWRAM-DSS core module to produce maps.

## 6. ACKNOWLEDGMENTS

The authors are grateful to the Royal Project Foundation, and especially to Dr Santhad Rojanasoonthon, for its coordination and leadership of the project. We also thank the Australian Centre for International Agricultural Research for assisting with the funding of the project. Drs Letcher and Jakeman provided helpful comments on the manuscript.

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