A Decision Support System for Integrated Water Resources Assessment and Management: A case study of the Upper Chao Phraya Headwaters, Northern Thailand

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Abstract The successful development of any Decision Support System (DSS) requires the collaboration of a multi-disciplinary team working together with all stakeholders. This is a generic requirement, but more so in developing countries, with significant village and tribal components to their society.

Here it is particularly important that socio-cultural as well as technical factors are considered in order to ensure that information is injected in a benefical way into the local decision-making process. DSS must be by neccessity located within government organisations, and be staffed by skilled personnel. However the challenge remains to develop information delivery networks that can build bridges with the less technologically skilled stakeholders.

The DSS being developed for an integrated water resource assessment project in the Ping Basin, Thailand assumes a participatory resource management model, where system objectives are determined by the visions, concerns and aspirations of all stakeholders, especially local communities. The DSS will generate land use and management options, based upon these visions and as constrained by the prevailing environmental resources, and the demands of larger scaled policy instruments (for example, those relating to downstream flooding). The DSS will have to incorporate (1) a complex suite of environmental and landuse models, (2) fine resolution spatial and temporal environmental and land use data, (3) trade-off algorithms, and (4) a series of support interfaces that will provide access for all stakeholders to all levels of the modelling process.

1. INTRODUCTION

Sustainable development has the twin goals of protecting the environment and promoting social equity and justice. The transition to sustainable living however requires finding solutions to often conflicting demands on land resources. Computer-based modelling and simulation has a vital role to play in helping stakeholders understand the environmental constraints underwhich they operate, in particular, the accumulated or downstream affects that they otherwise would be ignorant of, and the trade-offs between many potential land use options.

The problems are clearly not just biophysical, but contain socio-economic and cultural dimensions. Sustainability cannot be imposed but must emerge from the active participation of all key stakeholders. Decision Support Systems Technology is needed to bridge the gap between complex modelling and simulation methods and stakeholders with a diversity of backgrounds. This will help operationalise the concept of a participatory resource management framework (eg. Chambers, 1992; Kabutha *et al.* 1991).

This paper describes the Decision Support research component of a three-year collaborative project, starting late 1997, which will develop and apply an integrated approach to water resources assessment and management in the 40,000 km^2 Ping Basin in the Northern highlands of Thailand. The project is a collaboration between the Royal Project Foundation of Thailand and the School of Resource Management and Environmental Science, Australian National University.

Due to mounting and conflicting human pressures, stakeholders in the Ping Basin are facing a crucial policy problem typical of many basins in Asia, namely how to plan for the sustainable and rational utilisation, protection, conservation and management of land and water resources (Phantumvanit and Sathirathai, 1988). The central objective of the proposed project is to develop participatory and analytical approaches to assist the government and other stakeholders to identify and assess options for highland resource use, which will better provide for the sustainability of the inhabitants' natural and human resources. To achieve this objective, the project will examine, through the development of a decision support system and participatory decision making framework, the economic, environmental and socio-cultural implications of different levels and patterns of cultivation and other land and water use in one or two case study catchments within the Ping Basin.
The type of human activities taking place within catchments in the highlands of Northern Thailand have substantial and profound socio-cultural, environmental and economic impacts, both on-site and off-site

(downstream). An important issue of concern is the extent to which changes in land use in the highlands can contribute to downstream flood damage, sedimentation and the patterns of dry season flows. Another is the social impacts of measures adopted to curtail opium cultivation, swidden agriculture and deforestation. We hypothesise that alternate scenarios of pattern and intensity of land use may be identified which may provide for more sustainable development, by better promoting the inhabitants' socioeconomic and cultural welfare, and minimising impacts such as soil loss, flooding, drought and downstream water pollution.

The Decision Support component will develop decision support software and other tools (eg. Davis *et al.* 1991; Walker and Johnson 1995) incorporating simulation models, trade-off and optimisation algorithms coupled to spatio-temporal databases to perform simulations and visualisations of the biophysical, economic and social effects of land and water use options, and their level of uncertainty.

We define the Decisions Support component broadly to encompass not only a user-interface, but the entire complex of data, software and stakeholder dialogues that must be developed and integrated into the decision-making process that determines catchment management at the local and regional scales.

The contribution of this paper is to (1) articulate the linkages between a participatory decision-making framework and computer-based modelling and simulation, and (2) scope the range of data, models and stakeholder dialogues needed to develop an appropriate Decisions Support System for integrated catchment management in Northern Thailand.

2. RESEARCH OBJECTIVES

The aims of the decision support component are to:

- develop spatio-temporal databases at both meso and micro (subcatchment) scales as part of an integrated framework to link land use, productivity and other physical, social and resource information for the region.

- construct a decision support system (DSS) to aid research and policy developments for integrated land and water resource management by integrating the spatial database, environmental models and trade-off and optimisation algorithms. Existing DSS tools will be utilised as appropriate. However most existing systems fail to exploit the information potentials of high resolution environmental modelling. Hence the ultimate form of the DSS is difficult to predict at this point in time. This system will be designed to meet the interests of non-government as well as government stakeholders.

- undertake extensive systems modelling for representative catchments in the Ping Basin of alternate land and water use and management options in order to assess and visualise their net social benefit, including their externality implications and their impacts on social welfare.

- enhance the applicability of the DSS developed for land and water resource management in the Ping to other basins in Thailand and in the region.

3. SCALES OF ANALYSIS

The research methodology for this project has been designed using two nested scales of analysis: regional (the Ping Basin) and local (representative subcatchments).

Examining the regional context ensures that such influential factors as centralised economic development policy, the broader picture of water demand and the extreme downstream implications of highland resource use are considered. Ultimate assessment at basin scale, the capability for which will be designed into the DSS, will be undertaken in a follow-up project. Basin scale simulation is required in order to address at a more regional level the cascading and intersectoral nature of the impacts of water and associated land resource utilization. The assessment of management options is feasible at this scale, with development of the tools in this project's representative case studies, where useful data or information already exists. Subsequent extrapolation to the other catchments in the basin can be undertaken using appropriate models and spatio-temporal (GIS) databases.

The economic and sociocultural teams will concentrate on one or two representative case study catchments, from the Mae Taeng and Mae Chaem which feature villages in highland, upland and lowland reaches. These catchments are favoured because a relatively large amount of literature and data are available on these areas due to previous economic, social and ecological studies. Also, they encompass three common highland social issues which influence the policy problem to be studied in this proposed project. Firstly, the government's proclaimed protected watershed areas overlap with community settlements; secondly, the promotion of intensive cash cropping under contract farming systems has led to severe natural resources degradation; and thirdly, trekking tour operations have had extensive social impacts.

In addition, the Mae Taeng watershed is important in terms of rural-urban water allocation conflict as it feeds water to the major Northern city, Chiang Mai. The Mae Chaem features conflict between private sector industry (a mining company) and local communities which have formed an organisation aimed at protecting the forest resources. While quite a deal of basic data are available for these catchments, socioeconomic surveying will still need to be undertaken to generate information for the cost-benefit (economic and social) analysis of landuse options.

The biophysical team have selected 15 focal catchments of size 50 - 1000 km^2, including the three selected by the sociocultural and economic teams. Climate and discharge data are available for these but turbidity data will need to be collected. This number of focal catchments is required so that landscape attributes can be adequately related to catchment response dynamics, estimated from rainfall-flow-suspended sediment time series. The relationships obtained will allow the generation of streamflow and water quality time series (from climate and land use options) at smaller scales than are measured in the two representative subcatchments, as well as allow generation of such information in other parts of the Ping Basin in the follow-up project. The catchments have been selected on the basis of their representativeness of the major landscape types throughout the basin. For example, some are totally forested, most contain a mosaic of land cover types and major geological types, and the predominant range of slopes in the highlands are represented among the 15 selected.

4. RESEARCH METHOD

Aim: to develop spatio-temporal databases at both meso (regional) and micro (subcatchment) scales as part of an integrated framework to link landuse, productivity and other physical, social and resource information for the region.

The project will develop spatiotemporal databases at two scales: firstly, at the basin-wide scale with a grid resolution of about 100 m; and secondly, at the focus-catchment scale with a grid resolution of about 20m

- A grid-based Digital Elevation Model (DEM) will be developed for each scale, using the ANUDEM procedure developed by Dr. Michael Hutchinson of CRES. Fifteen years of ongoing research and development in Australia, North America, Africa and South East Asia has demonstrated that ANUDEM is the best available method to recover the shape of the landscape for hydrological modelling. ANUDEM uses elevation contours, stream lines and point elevations (if available) to generate the final interpolated grid of elevations. The basin-wide DEM will be produced from 1: 250 000 topographic mapping. At this scale, elevation contours for the Ping watershed are currently available and the stream lines have already been digitised. To produce the DEM it will be necessary to digitise all other required inputs, namely elevation contours and spot heights. Ideally, the focus-catchments should be produced from 1: 20 000 topographic mapping. However, there appear to be no officially published maps available at this scale. Hence, 1: 50 000 maps, currently available from the Royal Thai Survey Department, will initially be used to create a DEM for one of the focus catchments, Nam Mae Pan at Ban Kiu Ton Po. The utility of this scale will then be examined. If new, finer resolution data is required, this will be negotiated with the Photogrammetric Division of the DLD.
- Appropriately scaled remotely sensed data are needed to generate digital, spatially referenced, gridded coverages of extant landcover. Basinwide coverage will be generated using Landsat TM data, while focus catchment coverage will be produced from scanned aerial photography. The digital processing will need to be underpinned by reconnaissance field survey. The land cover classification will be developed so that they are compatible with agreed national standards. The land cover data are pivotal to the hydrological assessment and to evaluating the impacts of alternate land uses. The DEM will be used for environmental modelling of land use options in highland, particularly forested, areas where conventional resource inventory and analysis methods are inadequate. The DEM is also required to enable simulation of climatic impacts to the catchments. Together, the land cover and DEM provide the basis for extrapolating the results of focus catchment studies to the entire basin. Geological and soils data will be digitised from existing map sources.

Aim: to construct, through stakeholder consultation, an interactive Decision Support System (DSS) to aid research and policy developments for integrated land and water resource management with a decision support software shell which integrates various environmental modelling tools and databases

- We will develop a DSS to integrate databases, biophysical and economic models and, through what-if scenarios, allow for interactive sensitivity analysis. To suit its application context, the DSS will need to be portable, simple and robust. Various options are currently being evaluated. The challenge lies in integrating the ouput of high resolution focus catchment and basin-wide analyses with algorithms and procedures for examining the trade-offs between completing environmental, social and economic objectives.

Aim: to undertake extensive systems modelling for the two representative catchments (and, it is hoped, in a follow-up project for the entire Ping Basin), of alternate land and water use and management options in order to assess their net social benefit, including their externality implications and their impacts on social welfare

- Intensive analysis of data from our representative catchments is to be used to generate an understanding and a predictive capacity for other catchments in the Basin in a proposed follow-up project. An underlying goal is to be able to use landscape, climate and demographic data to be able to extrapolate the outputs to areas outside the focus catchments, utilising relationships between climate, landscape, land use, demography, agricultural productivity and environmental costs developed for the representative range of focal catchments.

- Application of these latter relationships in order to perform interpolation at smaller scales within the two representative catchments and the regional extrapolation in the follow-up project requires spatial data bases (and in some cases, such as climate, temporal data bases) on the model inputs. These are to be developed in the GIS and imported into the DSS. The models or relationships will also be interned as modules in the DSS. In this way, the DSS can be used to visualise spatial or temporal inputs and outputs, as well as perform scenario studies with hypothesized inputs for the entire basin or some part of it. The DSS can also be used to map stakeholder visions or constraints for the different parts of the Basin.

Aim: to ensure that the DSS is flexible enough to serve the interests of stakeholders.

- This will be achieved by consultation with Thai stakeholders, in parallel with the visions exercise, in the early stages of the project. The desirable functional features of the DSS will be identified and examined in association with the input and output requirements of each function.

- The models and data systems developed by the biophysical, economic and socio-cultural components will be integrated into the decision support systems (DSS). The DSS will be used for simulations and policy analysis using these integrated tools.

5. RESEARCH OUTPUTS

There are two principal scientific outputs. Firstly, the DSS will provide an assessment and management framework which will integrate participatory planning with scientific analysis and decision support tools; social, economic and biophysical data; and economic–environmental analysis of resource use options.

Secondly, the DSS will provide analysis and visualisations of spatial databases on terrain attributes, soils, vegetative cover, land use, climate and substrate and socioeconomic survey data. For the biophysical data this will be undertaken at meso (1: 250 000) scale for the Ping Basin, and at micro (1:50 000) scale for the focus catchments. Visualisation and integration of simulation model outputs of the effects of climate and land management in the one or two case study catchments (and in the second phase throughout the Basin). These data are required to drive the models in the biophysical component, and to enable the results of the focus catchment studies to be extrapolated in the second phase across the entire basin. The data will also be of longer term value to other resource management issues in the region such as the conservation of biodiversity. The combination of the socio-economic with hydrological and other biophysical data promises advances in integrative modelling techniques.

6. USERS OF THE DSS

It is anticipated that a broad range of stakeholders will use the Decision Support System either directly or indirectly. The direct users will primarily be technical personnel within government departments such as the Department of Land Development, Office of Highland Development, Electricity Generating Authority of Thailand, Royal Irrigation Department, Royal Forestry Department, Office of Environmental Policy and Planning, Office of Narcotics Control Board and the Department of Public Welfare. Through an integrated information base (incorporating the mapped visions of different stakeholders, databases, models and the outputs related to the pursuit of different management strategies), the various management agencies will be able to make more informed policy and planning decisions about land and water use options in the highlands of northern Thailand. Other users, including the Thailand Development Research Institute, the Tribal Research Institute, and some NGOs will be able to use the DSS to assess the impacts of management decisions and inform the political process from their own perspective.

A subtle aspect of software development for the Decision Support System is that its sophistication and heavy reliance on quantitative data biases its use in favour of some organisations, usually government and scientific ones. Further, the type of information included and the outputs can lead to interpretations more supportive of some stakeholders' interests than others. Local people are the most likely to be marginalised in software development. While we have only partial solutions to this type of bias, we are aware of it and the socio-cultural and decision support teams will take certain steps to redress it. These are the inclusion of cultural, value-based and other qualitative data in the decision support system, and input and review by people concerned to ensure equity in decision support. We are not pursuing the option of a less sophisticated decision support system which might conceivably be accessible to more users, since local people are unlikely to develop computer capacity to use any such system in the forseeable future, and we do not want to sacrifice the modelling sophistication required by the problem and by some of our clients.

The most difficult stakeholder group to disseminate information to is local people, yet they are important indirect users of the DSS. Local people are difficult to reach through representative processes, and literature is an inappropriate means of communication with them. We intend that the collaborators' field staff will maintain close communication with the local people in the catchments participating, disseminating summaries of research results in village meetings and other locally appropriate fora.

7. LINKAGES

Research methodologies in the biophysical, socio-cultural and economic components are closely integrated in terms of selecting focal sites to sample for data collection, and in terms of the information transfers that are to take place between the research components. This is important for consistency of data within the DSS.

Scenarios or management options generated by the regional and local stakeholders and local participation processes undertaken in the socio-cultural component (see Ross *et al.*, 1997) will be used as inputs to the biophysical land-use management simulation. This will ensure that management options being modelled in the DSS are 'real' and perceived as desirable by the different stakeholders.

Information from the biophysical component (see Jakeman *et al.*, 1997) and the economic component (see Mallawaarachchi *et al.*, 1997) on agricultural benefits will also be fed into the stakeholder process to provide feedback to the stakeholders on the benefits and costs of different visions and options for land use management.

Information from the biophysical component on flood stage height, water quality, and dam siltation will be fed into the economic component for calculation of off-site costs and benefits. Also, crop yields calculated in the biophysical component will allow on-site benefits of yields, and costs of and losses in land productivity to be calculated in the economic component.

Finally, the models and data systems developed during the project will be integrated into the DSS for simulations and policy analysis using these integrated tools.

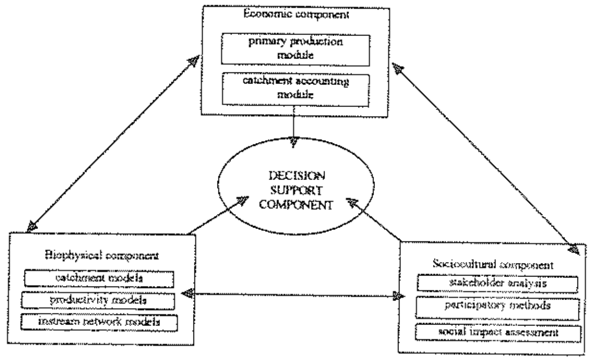

Figure 1: Linkages between the decision support component and other project components

8. SUMMARY/CONCLUSION

Decision support involves complex cultural considerations, in addition to the technical difficulties that must be overcome. In addition to computationally sophisticated software solutions, there is a parralel need to develop a suite of mechanisms that can deliver timely and useful information to various stakeholders with widely ranging levels of scientific expertise. In order to meet the needs of such a diverse client base, the DSS must also be capable of extracting data and information from any of the sub-modellig projects, and at any level of data integration or system analysis. We remain hopeful that computer-based interfaces can help bridge cultural and technical divides.

9. ACKNOWLEDGEMENT

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