Economic Analysis Framework for Integrated Water Resources Assessment and Management: A case Study of the Upper Chao Phraya Headwaters, Northern Thailand

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Abstract

This paper describes the economic research component of a three year collaborative transdisciplinary project supported by the Australian Centre for International Agricultural Research to develop and apply an integrated approach to water resources assessment and management in the Ping Basin. The Ping Catchment in the Northern highlands of Thailand faces multiple resource use conflicts within a fragile environment coupled with rural poverty. The integrative role of the economic research methodology and its links with the bio-physical and sociocultural components of the project are discussed. Linkages are identified to a proposed multi-attribute decision support system (DSS) to help identify and assess sustainable options for highland development for decision making at a strategic level.

1. INTRODUCTION

Ping Basin managers in Thailand, as do managers of multipurpose river basins throughout the world, face the crucial policy problem of how to plan for sustainable utilisation and management, including protection and conservation of land and water resources.

The Ping Basin in Northern Thailand has been a centre of economic activities for the last few decades, including deforestation, damming of rivers for irrigation, hydro-electricity generation and intensification of agriculture. Although these activities have provided valuable economic opportunities and contributed to the reduction in rural poverty to some extent, they are becoming increasingly unsustainable because of their onsite and offsite effects.

Onsite impacts include increased soil erosion, causing declining agricultural productivity. The off site impacts of these developments have manifested in increased sedimentation of lower reaches of the river causing extreme river flow regimes, urban floods and poor water quality.

In addition, over the past two decades, there has been a marked increase in immigration by lowland people seeking potential high returns from highland cash crops. The scarcity of arable land has increased as has agricultural intensification and the use of fertiliser and pesticides. Accompanying the agricultural intensification has been an increased use of low-cost gravity fed sprinkler irrigation systems (TDRI 1994). The greater contact with lowland people has gradually altered the traditional highland communities' perceptions of living standard. Some of these developments have also had negative social impacts on cultural traditions and values.

A key policy challenge facing the Thai government is, therefore, how to plan for the sustainable utilisation of natural resources in the best interest of the region (and the nation), while maintaining a balance between conservation and productive uses.

Conventional approaches to natural resource utilisation have tended to be top-down. Decisions about implementing large scale developments have been largely based on economic appraisal of individual projects. The belief that all values are commensurable, and that economic (cost-benefit) analysis alone can help resolve conflicts in use has led to its predominant use in the past.

These appraisals have tended to focus on short term economic gains and neglected the potential social and environmental costs (TDRI 1995, Tungittiplakorn, 1995). Such fragmented decision making processes of the past have allowed the over exploitation of land and water resources and major impacts downstream.

The application of cost-benefit analysis in particular has come under heavy criticism for its inevitable bias towards readily quantifiable market based values. Deficiencies in accommodating spatial distributions, temporal effects, non-market values and objectives, and the rights of and obligations to the natural environment has been the major focus of such criticisms (Godfrey-Smith, 1979; Enters 1992).

[#] This framework was developed while attached to ABARE, Canberra.

In particular, imperfections in markets, deficiencies in institutions, incomplete or poorly defined property rights, natural restrictions in the tradeability of environmental goods and services; and the presence of externalities, risks and uncertainties associated with natural resources have proved cost benefit analysis and making allocative decisions on the margin are largely inadequate (Bruenig 1986, Grimble and Wellard, 1997). Where equity and sustainability issues are also of concern cost-benefit analysis has also proved inappropriate. Adding to this problem is the absence of a multidisciplinary, ecological-social-economic, conceptual framework that could help guide governments to resolve conflicting resource use demands in a multi-user environment (Grimble & Wellard, 1997).

In an environment where decision making is becoming increasingly open and is involving stakeholder inputs at various stages, a holistic approach that accommodates dynamic processes, feedback mechanisms and control strategies have widely been advocated as a framework to model realities of economic-environmental phenomena (Costanza et al., 1993; Hannon and Ruth 1994 and Joubert et. al. 1997).

Generally there is an absence of integrated research methodologies that take advantage of recent methodological developments in individual disciplines and carefully analysed case studies. Many of these approaches are still in a conceptual stage (Grimble and Wellard 1997).

The development of an analytically rigorous framework will require a synthesis of approaches that take into account the interdependencies between the socio-cultural, biophysical and economic attributes of the region. The framework needs also to be flexible enough to accommodate changing needs and aspirations of the local people, the nation's desire to maximise the net long term economic prosperity and reflect the capabilities of the natural resources and the environment.

The objective of this project is to take a "holistic sustainable development" view and develop and apply a transdisciplinary framework in which economic, social, and environmental concerns are analysed in an integrated manner.

The integrated approach will focus on assessing the viability and sustainability of local economic activities and their interaction with the policies aimed at resource conservation. Such a framework will be designed involving various stakeholders and applied primarily in the Mae Chaem subcatchment in the Ping Basin, to provide for the sustainability of the inhabitants' natural resources, without impinging on opportunities for resource use downstream.

The primary focus of this project for the two catchments is thus directed towards the reorientation of agricultural and resource development activities to minimise externalities such as soil loss, drought and flooding.

1.1 The Integrated Framework

The project is designed as four interlinked components, biophysical, sociocultural, economic and decision support, as illustrated in Figure 1.

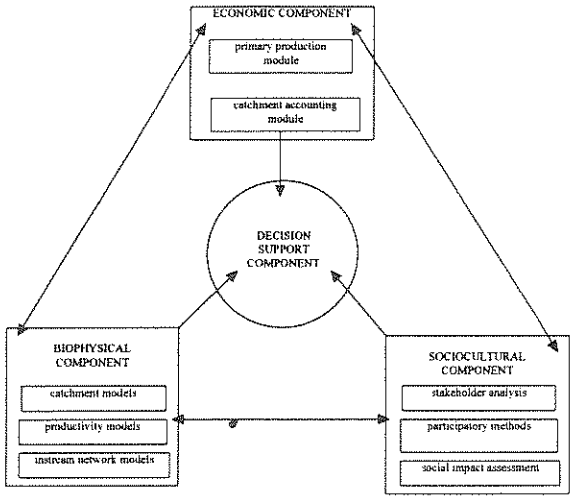

Figure 1: Linkages between the four project components

- The *biophysical* component will provide an understanding and assessments of the natural resource stocks and processes. It will also provide information about soil erosion to aid in the development of current and proposed water and land use options.
- The *socio-cultural* component is to identify stakeholders' aspirations for highland development, assess socio-cultural impacts of land and water use, and generate alternate land and water use options compatible with social, environmental and economic objectives.
- The *economic* component will assess on-site benefits as well as on-site and off-site costs of land and water use, using outputs from the biophysical component. It will also provide estimates of quantifiable economic costs and benefits of alternative management options consistent with social aspirations and resource constraints. The economic component will play an important role in translating the results of the socio-cultural and biophysical components across different geographic scales as well as across research disciplines (Figure 2).

- The *decision support* component will develop decision support software and other tools to perform simulations and visualisations of the biophysical, economic and social effects of land

and water use options, and their level of uncertainty.

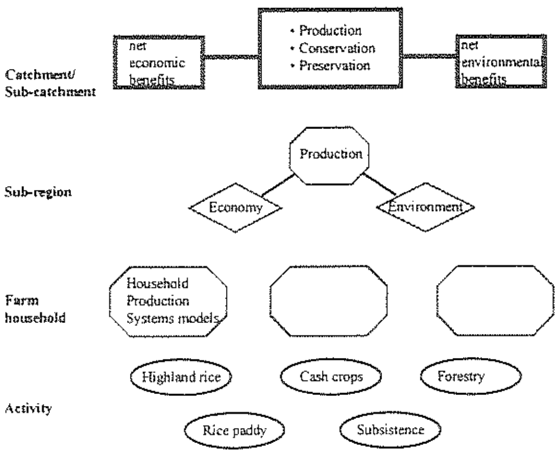

Figure 2: Linkages across activities and geographical scales from activity, farm household to subcatchment

In this paper only the economic subcomponent is discussed in detail. For details of the overall frameworks and other components see the papers presented at this conference by Jakeman et al; Ross et al; and Mackey et al.

2. ECONOMIC RESEARCH

The primary objective of the economic sub-project is to provide an analysis of profitability of current and alternative land use options for use in the decision support system.

More specifically, the economic sub project will:

- determine the current pattern of land use, water management, agricultural output and income patterns in selected subcatchments, but with a particular focus on Mae Chaem, in the Ping Basin.
- assess the potential resource capability to support alternative land use and water management options;
- develop quantitative relationships, in the form of bioeconomic models, to assess the profitability of current and prospective land use options and their externality implications in terms of economic-environmental tradeoffs; and assess the catchment-wide impacts of resource use options.

3. BIOECONOMIC MODELLING

The core activity of the research methodology is the development of a series of bio-economic models to represent the variability of the land-use systems in the Mae Chaem catchment.

3.1 Model Development

The modelling system will have several components and will be organised in a hierarchical order (Figure 2).

3.2 Crop Modelling

Individual bio-economic crop models will be developed for key crops and livestock activities in the Mae Chaem catchment. The profitability of different agricultural activities, including crop and animal farming, will be assessed using partial budget and gross margin analysis. The crop production model will also include the effects of onsite costs of soil erosion on cropping profitability

Agricultural activity modelling will provide input to *household agricultural production system modelling*, in particular for those activities for which reliable agronomic data is not available from field investigations. This activity will be undertaken in association with the biophysical team.

3.3 Farm And Village Level Assessment

These crop/animal bioeconomic models of agricultural activities will then be used to develop integrated household production system models. Spreadsheet–based activity analysis and partial budgeting, multi-criteria optimisation will be used to identify and refine potential household production systems at the village level.

The models will focus on the farm/household production interface and capture the influences of prices, policies and institutional set up such as water administration.

Alternative land use options identified by the stakeholders will be used to develop integrated household production systems, which are compatible with social interests, agronomic considerations, economic efficiency and the potential resource use capability. This multicriteria analysis will be used to provide a description and analysis at the village level of alternative agricultural land use options for different land use capability classes and their ranking in terms of social interest, environmental and economic criteria. This analysis will also help identify linkages at village level between agricultural and non-agricultural household activities. The latter will include, forestry, agroforestry, and traditional and contemporary improved agricultural options.

These agricultural production system models will be developed to analyse tradeoffs in the achievement of environmental and economics policy goals, within the constraints imposed by the sociocultural expectations, natural resource endowments and access restrictions.

3.4 Catchment Level Assessment

At the catchment level, quantitative methods will be developed to assess the profitability of various land use options and their externality implications in terms of economic-environmental tradeoffs. Hydrological and soil erosion models will be an integral component of these quantitative, biophysical-economic, models.

On-site and off-site impact assessments and GIS analyses will be used to determine the catchment-scale impacts (in terms of soil erosion and its effects on for example, changes in river discharge regimes, flooding) of preferred resource use options across the region.

Initially, it may be possible to scale up the results over each successive level following regional aggregation procedures used by Thai official statisticians. Mathematical Programming and GIS utilities used in various Murray Darling Basin studies (Mallawaarachchi *et al.*, 1995, 1996) will be used to develop catchment wide costs estimates for the Mae Chaem. Considering each local area as a case study, results of case studies will be extrapolated spatially with the assistance of GIS models that incorporate bio-physical attributes. Because of likely uncertainties in some data, sensitivity analysis and simulation will be extremely important. This will help develop better catchment-scale estimates of the impacts on the economy and the environment of various land use options developed for each of the local areas.

3.5 Regional Impacts - Regional Accounting

Development of an environmental accounting framework would be necessary to systematically account for production-environmental tradeoffs at a regional level. These accounts would include the value of degradation of resources associated with various feasible land use opportunities and the current land uses, values of environmental tradeoffs related to fertility and flood damage, and costs of defensive expenditure, such as management practices to mitigate soil erosion.

4. PROCEDURAL FRAMEWORK AND DATA COLLECTION

The procedural framework for this study, adapted from a framework for Sustainable Development Planning for Aboriginal Communities (Young and Ross 1993) and a framework for Integrated Local Area Management for Australia's Coastal Zone (Brown 1995), contains four iterative dimensions 1: Visions, Resources, Options and Practice. The details of this framework is discussed by Ross, *et al.* (1997).

4.1 Visions

Information on visions about land use options will be obtained from the collaborative work with the sociocultural team. These integrated visions for sustainable futures will guide the land use planning and development work coordinated and conducted by the economics team.

4.2 Resource Assessment

Local, regional and catchment level model development will no doubt require an extensive local knowledge and an understanding of the complexities and interactions at the local and catchment levels. This will include: an understanding of: the relative spatial positioning of cropping systems in a landscape (catenal sequence); and the relative importance of the various components of traditional farming systems, such as the home garden, lowland rice paddies and the upland allotments.

Currently available data on land classification for various uses will be used in conjunction with the remote sensing and other biophysical information being collected by the biophysical team (Jakeman *et al.* 1997). This will allow identification of areas for different production and conservation uses and limitations of certain land classes for certain land-uses. An understanding about the nature and current profitability of highland farming systems, with particular emphasis on its development path, pressure on resources, people and the environment is also important when identifying practical alternative land use options for consideration by the communities

These analysis will be undertaken for the two principal land use groups, namely :

- rainfed upland farming systems in the highlands and
- rice-based irrigated farming systems in the lower and middle reaches of the catchments.

4.3 Options

To identify most appropriate land use pattern will require an agreement on a set of alternative land use and water management options that are likely to be acceptable to the stakeholders, profitable and are capable of meeting resource sustainability and national policy objectives. The options will include non-destructive utilisation, conservation and development alternatives.

The Thai and Australian researchers will jointly identify and collect the required data and information for profitability of alternative land use options, including off-site costs and benefits. A range of methodologies will be used: including socio-economic surveys, literature review, stakeholder consultation involving Rapid Rural Assessment techniques and remote sensing and resource appraisal techniques based on bio-physical measurements.

General agreements about the viability and acceptance by the community of alternative land use options will be an integral component of the options analysis. The social acceptance analysis will be conducted with the sociocultural research team in a recursive manner. Profitable agricultural activities identified using the land use capability criteria will be further evaluated for their potential social acceptability by each social strata as identified by the socio-cultural analysis.

5 ASSESSMENTS, SIMULATION AND LINKAGES

Models provide a useful way of simplifying complex systems as an experimental tool particularly as the availability of data, time and resources largely dictate the level of precision that can be achieved.

A set of farming systems options will be developed and assessed under various productivity criteria. Financial and economic assessment of the alternative land use and water management options will be undertaken using land capability classifications and assessments of the overall merit of selected options using social acceptance analysis.

Information from the economic component on agricultural benefits will 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. The economic models and data systems developed during the project will be integrated into the decision support system.

6. OUTPUTS OF ECONOMIC COMPONENT AND DSS

The economic subcomponent will generate the following outputs:

- Description and overview of current land-use which will provide the basis for designing improvements to existing land-use systems.
- Development of a land-use profile in a GIS which will facilitate interaction with the biophysical component, by allowing comparisons between broader land-use categories and macro level biophysical attributes, leading into the land capability classification.
- A detailed profile of the household production system which will provide a description of the activities at household level, giving an indication of the relative importance of activities in each sector, such as agriculture, rural industry and other types of employment. This analysis will identify the components of smallholder farming systems, and their relationship to social aspirations.
- Quantitative description of the household production systems. The current level and patterns of activities at the household level, including relative factor productivities as observed through the household surveys, will be evaluated. This will provide the basis for conducting more detailed household level analyses, and identifying opportunities and constraints for improving current production systems. Existing activities which have potential for expansion will be identified.
- Relative merits of alternative production systems: economic viability, environmental impacts, social acceptability. A quantitative assessment of the relative profitability of alternative land-use options, their suitability in terms of arresting soil erosion, and potential social acceptability will be generated. This information will be used to identify potential agricultural options for developing land-use systems for each focal catchment.
- Bio-economic crop models. The crop models can be used for evaluating crop performance under alternate environmental and management conditions.
- Multiproduct farm models. The farm models will contain multiple enterprises with the capacity to evaluate alternate cropping systems and enterprise combinations to meet multiple objective design criteria, over time.
- Potential land-use options. The analysis will also lead to the selection of a range of potential land-use options that meet local resource constraints and are compatible with social, economic and environmental requirements.
- On-site costs and benefits of land-use options. This output, for each case study catchment, integrates the results of village level farm modelling, thus presenting estimates of on-site costs of land degradation associated with agricultural practices, and the total value of potential agricultural output from optimal land-use scenarios.

Aggregated onsite and off-site costs and benefits of land-use options will be incorporated into the DSS (Mackey *et al.* 1997). This integration will relate all the optimal agricultural land-use activities in each sub-catchment, with similar activities across the case study catchments. This linkage will allow opportunities for assessing land-use options to meet broader regional sustainability requirements and to assess both the on-site and off-site costs of erosion, resulting from rearrangement of activities according to social, economic and environmental criteria.

7. CONCLUSION

Economic data is but one set of information used often to resolve resource use conflicts; social, cultural and environmental values are also relevant particularly when there is insufficient market information or where all the costs and benefits cannot be quantified and there are other value sets to be considered. A flexible decision support system (DSS), which also helps to integrate different types of information, will be developed in this ACIAR supported collaborative project. Such a DSS will incorporate capacity for visual interpretation of scenarios across geographic scale and through time. These developments will draw on existing systems (Walker and Johnson 1996, Malafant and Fordham 1995, Hipel et al 1997).

The DSS will be designed to be user friendly and could be particularly helpful in discussing project developments with stakeholders, counterparts and other interested groups who may not be well conversed with complex analytical approaches that are being used to generate results. The DSS will also aid future policy analysis and decision making based on the identification and economic, environmental and social assessment of alternative resource planning and development options.

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9. REFERENCES

Brown, V., *Turning the Tide: Integrated Local Area Management for Australia's Coastal Zone)*. Summary of a research report for the Department of the Environment, Sport and Territories, 1995.

Brown, V., *Managing for Local Sustainability: Policy, Problem - Solving, Practice and Place*. Canberra: Commonwealth of Australia, 1997.

Bruenig, E., The tropical rainforest as ecosystem, Plant Research and Development, 24, 15-30, 1986.

Costanza, R., L. Wainger, C. Folke and K.-G. Maler, Modelling complex ecological economic systems, *BioScience*, 43, 545-555, 1993.

Easter, K., Dixon, J. and Hufschmidt, M., *Watershed resources management: An integrated framework with studies from Asia and the Pacific*; Studies in Water Policy and Management No 10, London: Westview Press, 1986.

Godfrey-Smith, W., The value of Wilderness, *Environmental Ethics*, 1, 309-319, 1979.

Grimble, R. and Wellard, K., Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities, *Agricultural systems*, 55(2), 173-193, 1997.

Hannon, B. and Ruth, M., *Dynamic Modeling*. Springler-Verlag, Berlin, 1994.

Hipel, K. W.; Kilgour, D. M.; Fang, L. and Xiaoyong Peng, The Decision Support System GMCR in Environmental Conflict Management, *Applied Mathematics and Computation* 83-117-152, 1997.

Jakeman, A.J. Saowapon, C., Jintrawet, A., Trisophon, K. Evans, J. and Wong, F., Biophysical Component of an Integrated Water Resources Assessment Project in the Upepr Chao Phraya Headwaters, Northern Thailand. Paper presented at MODSIM 97 Conference, Hobart, 8-11 December, 1997.

Joubert, A.R., Leiman, A., de Klerk, H. M., Katua, S. and Aggenbach, J.C., Fybos (fine bush) vegetation and the supply of water: a comparison of multi-criteria decision analysis and cost-benefit analysis *Ecological Economics* 22: 123-140, 1997.

Mackey, B., Trisophon, K., Ekasingh, M., Sangawongse, S., Wong, F. and Jakeman, A.J., A Decision Support System for Integrated Water Resources Assessment and Management: A case study of the Upper Chao Phraya Headwaters, Northern Thailand. Paper presented at MODSIM 97 Conference, Hobart, 8-11 December, 1997.

Malafant, K.W.J. and Fordham, D.P., Decision support systems and visualisation tools for modelling biophysical, production and socioeconomic futures in irrigation regions. In: *Proc. International Congress on Modelling and Simulation*, University of Newcastle, P. Binning et al. (eds), Vol 3, pp. 236-244, 1995.

Mallawaarachchi, T and Hall, N. *A framework for developing an integrated modelling system for water policy analysis*. Paper presented to the 39th Annual Conference of the Australian Agricultural Economics Society, Perth, University of Western Australia, 14-16 February, 1995.

Mallawaarachchi, T, Walker, P.A., Young, M.D., Smyth, R.S., Lynch, H.S. and Dudgeon, G.,: GIS-based integrated modelling systems for natural resource management, Agricultural Systems, 50(2):169-189, 1996.

Ross, A.H., Ayuthaya, P.N., Wong, F., Integrating Socio-Cultural With Economic and Environmental Issues in a River Basin: A Case Study of The Upper Chao Phraya Headwater, Northern Thailand. Paper presented at MODSIM 97 Conference, Hobart, 8-11 December, 1997.

TDRI, *Assessment of Sustainable Highland Agricultural Systems*, Bangkok: TDRI, pp. 149,. 1994.

TDRI, *Natural Resources Management in Mainland Southeast Asia*, Bangkok: TDRI, pp 127, 1995.

Tungittiplakorn, Waranoot, 'Highland-lowland Conflict over natural resources: a case of Mae Soi, Chiang Mai, Thailand. *Society and Natural Resources*, 8: 279-288, 1995.

Walker, D.H., Johnson, A.K.L., Delivering flexible decision support for environmental management - a case study in integrated catchment management. *Australian Journal of Environmental Management*, 3(3), 174-188., 1996.

Young, E. and Ross, H., Sustainable Development Planning for Aboriginal Communities. *Australian Aboriginal Studies*, No. 1, pp. 91-92, 1993.