Integrating biodiversity conservation and sustainable agricultural development in the tropical landscapes of Southeast Asia: proposal for a network of landscape modelling case-studies

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Abstract

Increasing agricultural production and the conservation of biodiversity are policy and management goals for many Southeast Asian landscapes. The problem is how to conserve biodiversity in tropical landscapes given the expected growth in needs for food, fibre, water and energy into the middle of the next century. Maintaining biological diversity depends on the spatial arrangement and complexity of land use systems on the landscape: fragmentation patterns and the sizes of remaining habitat elements are clearly related to the risk of extinction. The spatial arrangement of land cover elements and the consequent impacts on biodiversity also have implications for ecosystem functioning, and hence the goods and services that human societies depend upon (eg. provision of fresh water, retention of nutrients, flood control, etc) In addition, the ways in which natural disturbances like fires, pests and diseases propagate through a heterogeneous landscape clearly depends on its structure and biological diversity. Research is therefore needed to develop policy options and strategies that consider the overall mixture and configuration of land use systems and how they interact. The Southeast Asian Impacts Centre (IC-SEA) is now developing a network of landscape modelling case-studies in the Southeast Asian region to refine and apply some of the recently developed modelling tools to specific integration problems. This landscape initiative, in turn, will feed into two other initiatives: a network of research projects being developed under the START Global Change program for an Integrated Study of Global Change and Sustainable Development in Southeast Asia; (2) implementation of the Global Change & Terrestrial Ecosystem Core Project Focus on Global Change and Complexity.

1. INTRODUCTION

1.1 Integration Challenge

Increasing agricultural production and the conservation of biodiversity are policy and management goals for many Southeast Asian landscapes. The problem is how to conserve biodiversity in tropical landscapes given the huge expected growth in needs for food, fibre, water and energy into the middle of the next century. If these nations follow the same development pathways for agriculture as the western world it seems almost inevitable that these needs will be met by the continued conversion of vast areas of natural forest to crop lands and low diversity plantations with dire consequences for biodiversity.

In many parts of Southeast Asia changing land use, especially intensification, is already having impacts on ecosystem functions and the services provided by landscapes. Soil degradation and declining water quality are now considered major environmental problems by most Southeast Asian governments (United Nations Environment 1997).

The integration challenge is likely to become more difficult with the impacts of concurrent regional and global environmental changes. Transboundary air pollution is already a major political issue in the region. Increasing levels of CO_2 in the atmosphere and possible future climate changes could compound existing environmental problems.

1.2 Landscapes

Maintaining biological diversity depends on the spatial arrangement and complexity of land use system on the landscape; fragmentation patterns, the sizes of remaining habitat elements, and the nature of the agricultural matrix, are all related to risks of extinction. The spatial arrangement of land cover elements and the consequent impacts on biodiversity also have implications for ecosystem functioning, and hence the goods and services that human societies depend upon (eg. provision of fresh water, retention of nutrients, flood control, etc). Riparian habitats may be particularly important in filtering sediments and retaining nutrients in flood plains. In addition, the ways in which natural disturbances like fires, pests and diseases propagate through a heterogeneous landscape clearly depends on its structure and biological diversity.

Successful integration, therefore, implies not only that biodiversity be maintained and agricultural production increased, but that this is achieved without large adverse impacts on other landscape functions. For example the provision of clean water.

This requires a landscape perspective in addition to work on improving the sustainability of individual land use systems. Research is needed to develop policy options and strategies that consider the overall mixture and configuration of land use systems and how they interact.

The purpose of this paper is to develop a research program for a network of analytical case-studies of the integration challenge in Southeast Asia.

2. LAND USE, BIODIVERSITY AND ECOSYSTEM FUNCTION

2.1 Paradigm Solutions

A wide range of strategies have been proposed and are being tried, in Southeast Asia and elsewhere in the tropics, to solve the "integration problem". At their extremes they can be characterised by the way they treat natural biodiversity: isolate, use or incorporate.

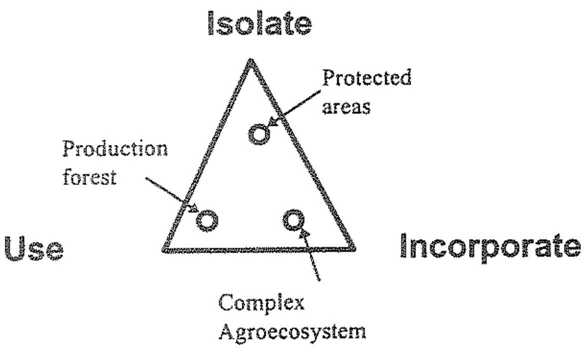

Figure 1. Paradigm solutions for managing natural biodiversity in production landscapes.

The *isolate* paradigm, modelled on the National Park System of developed nations, is to create protected area systems where the primary management goals is conservation. In more sophisticated versions attention is also paid to managing the matrix through buffer zones and the creation of habitat corridors to link areas.

The *use* paradigm is broad, ranging from logging native stands, through collecting fuel wood and non-timber products, to bio-prospecting for new pharmaceuticals or agricultural genes (eg. Janzen 1992). Some schemes, focus on a key natural resource, such as water or timber, and aim to integrate (or compromise) the uses of that resource.

The *incorporate* paradigm is similar in that biodiversity is used, but it takes complex agro-ecosystems, perhaps in landscapes transformed by human actions for centuries, as it's starting point, and looks for ways to increase biodiversity, through maintenance and re-introduction of useful species, in agricultural production areas (eg. Ramakrishnan 1995). Management changes aimed at increasing production and profits, however, often lead to decreases in biodiversity (Noordwijk et al. 1997).

Thus, in the isolate and use paradigms, natural biodiversity is segregated in space from mainstream agricultural production, whereas in the incorporate paradigm they are integrated at fine scales. In deciding where policies should lie in this use-incorporate-isolate space a series of generic questions arise :

1. Should different land uses be integrated or segregated in space?
2. Should the overall intensity of land management be increased?
3. Which combination of land uses should be promoted in the various land cover units?
4. Should specialisation or diversification of land uses be promoted?

In most places integration is not being achieved. This underlines the need for improved policy and resource management responses. On the one hand this implies a need for better application of existing research-based knowledge and inter-institutional cooperation. On the other hand, it requires a better appreciation of the policy process by researchers. At a more fundamental level there is also a need to improve understanding of the relationship between ecological complexity, landscape structure and ecosystem function.

2.2 Ecological Complexity and Ecosystem Function

Land use and land use changes have demonstrable impacts on ecosystem function and biodiversity. The relationship between biodiversity, or "ecological complexity", and ecosystem function, however, is less well understood, but an active area of research. It is not clear, for example, how much redundancy exists in ecological communities – that is, whether losing 5 or 20 or 50% of the species will make much difference. It is also not clear whether the loss of "keystone" species could lead to a cascade of extinctions because of their role in providing structure, critical resources, modifying disturbance regimes or other influencing other ecosystem functions. Insights from the study of invasions, however, demonstrate that single species can have large effects on biodiversity and ecosystem functions.

3. A NETWORK OF LANDSCAPE CASE-STUDIES

3.1 Rationale

An individual study cannot achieve the generality required to develop policy and management guidelines. This requires a set of case-studies. A top-down approach where every study addresses the same questions with the same tools, may make inter-comparison of results easier, but will fail to address the specific management issues in each area. Moreover, a top-down approach is to difficult to implement. A network approach is therefore recommended. In this approach each case study focuses on specific issues of importance to local management and policy. However, by working under the same broad framework and participating in integration activities, the various studies can gain mutual benefit from each other's experience and wider generalisations about the region become possible.

3.2 Scope and Objectives

The core activity of the program is to develop dynamic simulation models to examine how, at the landscape scale, land use and cover changes associated with agricultural production and use of biodiversity may influence biodiversity and production in the short and long term. This includes examination of the effects on other key ecosystem services because these will also affect the future capability of the landscape to produce and conserve biodiversity.

The main questions to be addressed are:

1. What are the biophysical implications of landscape structure and dynamics for biodiversity, agricultural production and other ecosystem services?

2. What are the potential socio-economic implications of implied changes in biodiversity and agricultural production?

In this network approach it will be up to the individual case-studies to develop their own set of specific questions. Some challenging and cross-cutting examples are:

1. What network of conservation reserves, particularly along altitudinal gradients, will maximise biodiversity conservation under projected changes to the Asian monsoon?

2. What mosaic of conservation reserves, production forests, complex agroecosystems and rice fields optimises water and nutrient retention under a changing monsoonal pattern?

3. How will global change interact with the distribution of land use and covers in the landscape to influence the movement of seed predators, seed dispersal agents, weeds and pathogens?

3.3 Framework

An analytical framework for the study is given in Figure 2. Landscape structure is a product of land use and cover change processes (Figure 2) It might be measured by the diversity of ecosystems or land covers present or some measure of their connectivity. Fragmentation and the introduction of novel land uses, for example, can produce increases in diversity at the landscape scale, while at the same time reducing species diversity.

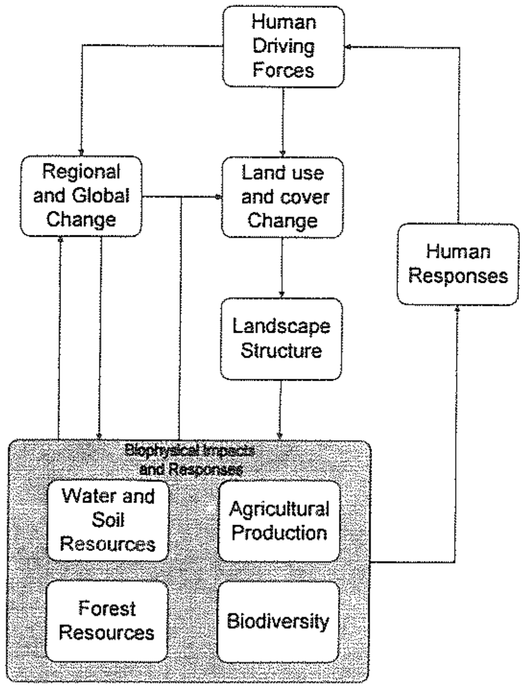

Figure 2. A framework for analysing the impacts of landscape structure on biodiversity, agricultural production and other ecosystem goods and services.

Land use and cover changes are influenced by many local, regional and global processes (Figure 2). Human driving forces (population, lifestyle change, etc.) as well as biophysical constraints and drivers need to be considered.

The biophysical and socio-economic implications of changes in landscape structure and other environmental changes include impacts on agriculture, biodiversity and other ecosystem goods and services. Some of these impacts in turn have transboundary effects and in their aggregate may contribute to regional and global environmental change. Human responses to the biophysical impacts are complex and feedback modifies their influence and their drivers. Some key human responses for this study include protected area management strategies, land development policies and investments in agriculture.

3.4 Activities and implementation

The first phase of the study should take a 2-3 years to implement and would involve the following key tasks :

- a workshop with electronic follow-up to refine proposals for individual case studies
- consultation and briefings with key stakeholders to secure institutional support within countries for the case-studies and to ensure that the problems tackled are policy relevant

- a workshop on methodology emphasising modelling tools
- establish a co-ordination node for the network
- an electronic communications, database and information system to support the sharing of models, databases and expertise
- a series of electronic conferences to review progress and synthesise the results of the case-studies
- a synthesis workshop that produces a quality summary publication and action plan to follow-up the most promising case-studies

An important consideration will be the choice of case-studies study sites and teams. This should take into account existing initiatives in the region which have already gathered or assembled some of the datasets needed to conduct the landscape modelling activities. For example, the recently completed SARCS/LUCC Southeast Asian case studies have produced datasets on land cover change and socio-economic variables over 5-10 year periods in sites in Thailand, Indonesia, Philippines and Malaysia. The Alternative to Slash and Burn (ASB) Project likewise has good datasets for sites in Jambi Province, Indonesia (van Noordwijk et al. 1995).

4. MODELLING LANDSCAPES

4.1 Overview

To help understand the implications of different land development trajectories tools, will be needed to :

1. Analyse the feasibility of reaching certain policy goals and targets given constraints in land capabilities and future demands for agricultural production.

2. Explore the effects of introducing new land use systems into the landscape matrix.

3. Explore the implications of alternative landscape designs.

For most problems this will require a variety of modelling and analytical tools either coupled together or integrated in a new model. The main components follow the conceptual framework (Figure 2) and will be discussed in turn.

4.2 Land Use and Cover Change

Land use and cover change models and analytical tools are needed to summarise knowledge about human driving forces into scenarios of land use and cover change (Figure 2). A couple of approaches will be needed:

- projections using historical observations and state-transition models
- statistical regression models relating probabilities of land use transitions with biophysical and socio-economic variables
- modifying scenarios of change based on stated policy options
- integrated dynamic models of land use and cover change

Integrated dynamics models are the ideal because they potentially could capture some of the important feedbacks as a landscape develops. However, they are also the most complex. A good example of the later approach is the CLUE (Conversion of Land Use and its Effects) model which integrates human and biophysical drivers of land use change (Veldkamp & Fresco 1996).

4.3 Landscape structure

Given scenarios about how land use and cover may develop over time, through direct transformation by humans or other environmental changes, analytical methods will be needed to describe how these influence landscape structure.

The aim of these studies should be to develop simple measures of landscape structure, for example, describing diversity and degree of fragmentation. Theoretical simulation experiments will be useful for understanding the behaviour of such summary statistics.

These measures could be then used in testing for more general relationships between landscape structure and the actual or forecasted impacts on biodiversity, agricultural production and ecosystem functions.

4.4 Implications for Biodiversity, Production and Ecosystem Services

The major modelling effort needed in this study is to examine the implications of landscape structure for biodiversity, production and ecosystem services.

The range of modelling tools that are potentially useful is very large, but these fall into a couple of groups.

- ecosystem process models of crop, forest and plantations
- disturbance propagation models
- fluid dynamics and soil erosion models

A limitation of most ecosystem and disturbance models is that they were developed to examine single ecosystems or land covers. If spatial interaction is minimal then it would be a simple matter to apply individual ecosystem models and then combine results using GIS. To properly address the integration issues, however, will need methods to handle the interaction of ecosystems or land covers. The challenge will be to eliminate as much detail as possible from the individual ecosystems, but not so much that the final model is meaningless and cannot incorporate real feed-backs.

Large basin models of run-off and erosion responses to landscape structure are also needed. The challenge for these models is how to incorporate key feedbacks: for example of the impacts of global changes on vegetation structure.

4.5 Socio-economic models and decision support systems

Finally, to support the "Human Responses" (Figure 2) it will be necessary to develop models to explore the socio-economic consequences of the landscape dynamics. In it's simplest form this may just assign area-weighted values for production and conservation to different areas. At it's most advanced it would need to be integrated dynamically within the land use and cover change model. Either way the outputs of these analyses will be useful inputs to algorithms for developing decision support systems on appropriate land uses and landscape configurations (eg. Faith & Walker 1997).

5. CONTRIBUTIONS AND LINKAGES

5.1 International Global Change Programs

A network of landscape case-studies would contribute to and benefit from linkages with the international global change programs.

5.2 Southeast Asian Impacts Centre

The Southeast Asian Impacts Centre (IC-SEA) studies and supports research on the impacts of global change on terrestrial ecosystems in Southeast Asia. Through previous training workshops, fellowship and equipment grant programs, it has helped develop a network of ecosystem modellers. Previous activities have concentrated on individual ecosystems, namely, forests, rice and complex agroecosystems. The fourth research theme aims to integrate these previous efforts by focussing on the multiple ecosystem landscape scale. The proposed landscape network described in this paper would launch this fourth theme.

5.3 SARCS Integrated Study

The Southeast Asian Regional Committee for START (or SARCS) aims to facilitate interdisciplinary research on the biophysical and human dimensions of global change in the Southeast Asia region. A Science Plan for a new Integrated Study is now being developed (Lebel & Steffen 1997). It builds upon earlier and current research on, for example, land use and cover change, greenhouse gas emissions, climate and elevated CO_2 impacts on crops and forests, and studies of coastal zone impacts. The list of Core Themes in table 1 gives an idea of the broad scope of the study.

The overall goal of the SARCS Integrated Study is to describe, understand, integrate and predict land use and land cover changes, the natural and socio-economic factors that drive them, and their consequences for the sustainable development and management of the humid tropical marine, coastal and terrestrial ecosystems of Southeast Asia, with the primary focus on the coastal zones and continental shelf seas. This goal encompasses the full range of processes which impact on the coastal zone, including those which occur in terrestrial ecosystems higher up the catchments. The Study's overall goal is also aimed at contributing to an understanding of the role of Southeast Asia in the Earth system.

Table 1. Core Themes of the proposed SARCS Integrated Study

Core Themes
1. Industrialisation and Urbanisation
2. Land Use, Land Degradation and Decision Making in the Rural Hinterland
3. Institutions and environmental regimes
4. Climate Variability and Change
5. Biophysical Responses: System-level Process Studies
6. Biophysical Responses: Extensive Observational Studies
7. Past Environmental Changes
8. Integration and Synthesis
9. Sustainable Development Strategies

Achieving this goal is way beyond the capabilities of individual organisations in the region. The Integrated Study will, therefore, be based on a coordinated set, or network, of experimental, observational and modelling studies involving various ongoing and planned regional research programmes.

The proposed network of case-studies would help synthesise studies under Core Themes 2 and 5 and contribute to the overall integration and development of sustainable development strategies (Core Themes 8 and 9).

5.4 GCTE Focus 4

Global Change and Terrestrial Ecosystems (GCTE) is a core project of the International Geosphere-Biosphere Program (IGBP). The Focus 4 research effort deals with global change and ecological complexity. The proposed landscape network in Southeast Asia would contribute to understanding some of the interactive effects of global change on ecological complexity and methods for modelling the responses of ecological complexity to global change. Linking into similar efforts elsewhere in the world, especially in the Amazon and Tropical Africa would bring mutual benefits.

6. TOWARDS BEST-PRACTICE

The ultimate objective of the Southeast Asian landscape case studies is to move towards better management. The analytical case-studies if implemented and efficiently linked to other programs would lead to a better understanding of the implications of landscape structure for biodiversity, ecosystem function and agricultural production.

This is far from being practical advice on how to implement "best-practice". This will require, in addition to the technical research described above, a commitment to participatory land use planning in which the visions and goals of key stakeholders are acknowledged and reconciled (eg. Tan-Kim-Yong 1993). It is only through substantial effort in this area that there is any chance of conducting relevant (needed) research, and secondly of having research-based knowledge implemented.

What might "better-practice" involve? I suggest that to integrate biodiversity conservation and agriculture development goals under global environmental change we need ways of managing ecosystems in the landscape which are robust, adaptive, sustainable and participatory.

They need to be robust to cope with future environmental changes and surprises; adaptive, so that we can learn and correct our mistakes in mid-course, sustainable, so we, our neighbours and our children can attain a good quality life, and participatory so that powerful individuals or groups do not take control of the social development and environmental agendas.

Even when there has been political support for the idea of integration, success in achieving integrated landscape management has been rare. Economic, social, and environmental problems are considered separately by researchers, and the proposed solutions implemented by different institutions. Integration is needed at many levels not just in model analysis of the interactions between land uses in a complex landscape

The challenge is to argue and demonstrate that integrated landscape management, and the policies that promote such practices, will improve the ability of nations to meet their long-term food, fibre, water and energy needs.

7. ACKNOWLEDGEMENTS

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