Asia-Pacific Network for Global Change Research

INITIAL SYNTHESIS OF LAND-USE AND LAND-COVER CHANGE RESEARCH IN ASIA AND THE PACIFIC

A summary of APN-funded research activities focused on understanding land-use and land-cover change as an agent of global change in Asia and the Pacific

APN
Asia-Pacific Network for Global Change Research

Ⓒ First published in 2003

Printed in Kobe, Japan

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Preface

In recent years the Asia-Pacific Network for Global Change Research (APN) has funded several global change research projects with a focus on land-use and land-cover change in the Asia and Pacific region. Many of the projects have been individually producing important results relating land-use and land-cover changes to the carbon cycle, trace gas emissions, ecosystem dynamics, forest management, human dimensions and drivers of land-cover change, and data and information systems.

The aim of this report is to provide an *Initial Synthesis* of APN-funded research related to land-use and land-cover change. The report contained herein is the product of an APN workshop convened at the APN Secretariat in Kobe from 9-11 September, 2002. The workshop also provided a venue for the community of APN-funded Principal Investigators who have been active in land-use and land-cover change related research to compare their results and identify key common emerging questions, and to assist APN in formulating key priority areas for future projects.

The *Initial Synthesis* presented in this publication will provide APN members, key scientists, and decision- and policy-makers within the region with:

- An evaluation from the perspective of its key investigators and the current results of prior APN investments, and
- An initial synthesis of overall insights and accomplishments as well as directions for future investments.

One of the major conclusions is that APN strategies for future projects and for leveraging current results to the benefit of policy-makers should be built on the framework of existing projects in the region. APN should now begin to invest in efforts that will lead to land-use and land-cover decision support systems that would include a standard land cover classification system, baseline datasets and land-use and land-cover change detection analyses, assessment of areas of most rapid change, models of the drivers of change with both diagnostic and prognostic capabilities, risk assessment and environmental indicators.

The incorporation of a formal synthesis process in future land-use and land-cover change research seems to be a very promising and ***effective way for APN to both coalesce its individually-funded projects into a more coherent regional perspective*** and, at the same time, chart future programme initiatives and key priorities for future investments. Further discussions will identify mechanisms to provide on-going synthesis studies. Synthesis is not a one-time event but a process within both individual projects and the programme as a whole. As a result this *Initial Synthesis* outlines recommendations for future steps in the development of active synthesis efforts in the Asia and Pacific region.

Message from the Director

The endeavour to create an *Initial Synthesis* of APN-funded activities related to Land-use and Land-cover Change in the Asia-Pacific region was a new and challenging activity for APN. This activity has paved the way for more synthesis studies of not only APN-funded activities, but other related activities in the region and APN now hopes to expand this by covering other very important aspects of global change. I would like to extend my heartfelt thanks to all of the people who made this publication possible.

Sombo T. Yamamura
Director, APN Secretariat

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1 Introduction and Overview

Background

The Asia-Pacific Network for Global Change Research (APN) has been funding for several years a wide variety of important research projects in Southeast Asia focused on land-use and land-cover change. The programme has dovetailed with existing global change programmes of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP), including the SysTem for Analysis, Research, and Training programme (START), and has supplemented these programmes and their projects with new sources of support, which enhance the linkages between science and policy- and decision-making. Much progress has been made in the region supporting both fundamental research on important global change questions related to understanding drivers of land-use change, the impacts of land-use change on the global carbon cycle, the effects of land-use and land-cover change on biodiversity and ecological structure and function, forest management, sustainable development, monitoring and information systems, and spatial decision support systems.

This support has also focused on developing human resource capacity and building active networks of collaborating scientists and institutions. Considerable gains have been made using modest amounts of funds in the right places to support long term collaborations, many of which bring considerable matching funds and local institutional partnering. This twinning of support for research and capacity building has been fundamental in developing a kind of training-by-doing approach to capacity building, which provides foundations for long-term research, even to the point of supporting groups that eventually have become self-sufficient and self-supporting within the region.

Funding from APN has also made it possible to bring Asia-Pacific scientists into the larger international community of active global change scientists and, at the same time, made the region a respected and desired place for international participation and cooperation. This opening up of the region has been important for creating opportunities for Asia-Pacific scientists in the international programmes and for creating long standing bi-lateral and multi-lateral programmes between Asia-Pacific institutions and scientists and those in Europe, the Americas and elsewhere in the world. The groundwork for significant cross-region comparative work has been laid. The importance of the region in the global agenda has been established.

In 2002, the APN convened its funded investigators in a workshop to assess and synthesize recent results and progress in land-use and land-cover change related

research in Asia and the Pacific. The results of this workshop were edited into this *Initial Synthesis* report.

Why Study Land-use and Land-cover Change?

Land-use and land-cover change (LUCC)[1] is central to the interests of the science of global environmental change. It is a significant agent of change which influences, and is affected by, climate change, loss of biodiversity, and the sustainability of human-environment interactions, such as food and fibre production, water resources use, biological diversity, and human health. Land-use and land-cover change is thus a significant cause, or forcing function, of global change, and the medium on which much of the human responses to global change will take place. It is clearly an essential component in all considerations of sustainability.

To understand the role of land-use and land-cover change, it is important to define the following:

- land cover,
- land-cover change,
- land use, and
- land-use change.

Land cover is the actual distribution of vegetation, water, desert, ice, and other physical features of the land, including those created solely by human activities such as mine exposures and settlement.

Conversion and *modification* of a cover type constitutes *land-cover change*. Conversion refers to changes from one cover type to another. For example, the conversion of forests to pasture is an important land-cover conversion in the tropics, while

FIGURE 1-1: Slashed forest being converted to agriculture field in Ratanakiri, Cambodia (SEARRIN)

[1] While APN recognizes the LUCC Core Project of IGBP/IHDP, the term **LUCC** has been used throughout this report as a general acronym for **land-use and land-cover change**.

abandonment of cultivated land and the regeneration of forests are taking place in parts of the mid-latitudes. Land-cover change may also involve a significant alteration in the existing cover, affecting its structure or function (e.g. involving biomass, productivity, or phrenology) without a wholesale change to another cover type. We refer to this change as modification. Indeed, long-term and chronic modification can eventually result in conversion.

Land cover conversion operates through many pathways, the constellations of which form specific processes. For example, deforestation leads to many types of land cover, but one common conversion process entails cutting, burning, and even planting of grass to create a pasture.

In turn, site abandonment may lead to succession to a secondary forest. These pathways and processes, such as deforestation, desertification, wetland drainage, or agricultural intensification mediate the conversion or modification of land cover. Thus they can be envisioned as forcing functions, which have direction (forest to pasture or pasture to forest), magnitude (amount of change), and pace (rates of change). It is important to recognize that many land cover conversion pathways exist and are differentiated globally and over time. The study of land-use and land-cover change focuses much of its effort and emphasis on understanding the specific conditions and controls - both biophysical and social - which determine these pathways.

One key determinant of *land-cover* change is *land-use* change. Land use is the intent and management strategy placed on a land cover type by the human agents, or land managers. Forests, for example, could be used by foresters to selectively log for profit, by rubber tapers to harvest for subsistence wages, by tourists for recreation, or by no one. Shifts in intent and/or management constitute land-use changes. The specific factors, which determine land-use change, are thus central to the characterization of land-cover change, and invariably these factors are tightly coupled to a variety of social, economic, and institutional variables.

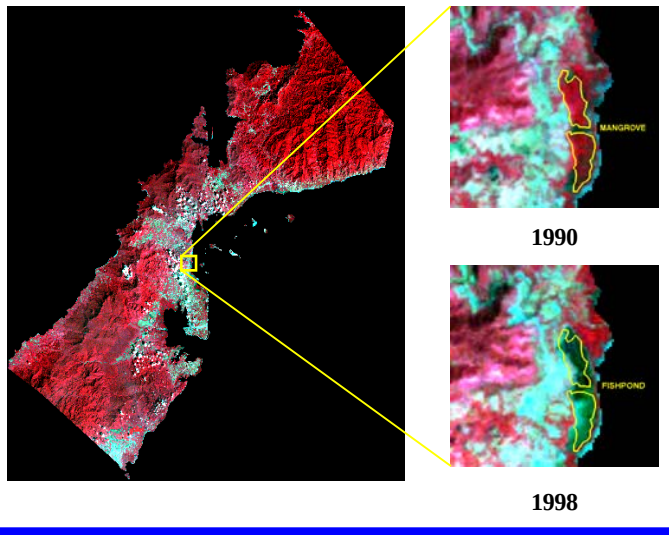


FIGURE 1-2: Landsat Images Showing the Conversion of Mangrove Forests to Fishponds, Palawan Island, Philippines

Land-use change invariably elicits land-cover change, if not conversion then modification. For example, the

conversion of forest to pasture occurs in an effort to convert the land use from rubber tapping to cattle ranching. Land-use change thus drives land-cover change. It is the means by which human activity appropriates the products of net primary productivity as determined by a complex set of socio-economic factors. Land use involves properties of scale, intensity, and tenure, among others that are not necessarily inherent in land cover. Small-scale, subsistence agriculture is not synonymous with large-scale commercial enterprises, even if the land cover type is the same, for example, open pastureland or irrigated rice fields.

The challenges facing land-use and land-cover change scientists will, because of the integrated and interdisciplinary nature of the research problems, involve a number of different tasks. These vary from monitoring the magnitude and rate of land-use change and land-cover change (e.g. through remote sensing and field observation), through analysis on the local scale of the social and economic forces that lie behind such changes, to the development of models (both formal and informal). These, in turn, can be used to predict future changes on a variety of scales (local, regional and global) and will aid in painting a picture of how land use and land cover fit into the overall scheme of global environmental change.

Because the outcome of *land-use change* is *land-cover change* and its concomitant effects on the Earth's major life support systems, the perceived emphasis of LUCC is a study of the forces that drive cover change. It is also true that LUCC is a study of its own internal processes, of a system of social and biophysical factors that we still do not understand very well. Because LUCC is integrally part of social organization, its study will greatly transcend the perspective of it driving *other* global changes. For example, Richards (2000) has elaborated on the central role of property rights in the study of LUCC, and this theme informs us about social organizations and modes of accumulation over time and geographically in ways which are not revealed in analyses of biophysical responses of LUCC. To this end the implementation of LUCC will remain significantly trans-disciplinary.

Emerging Global Change Research Priorities

Entering this decade, the term ***global change*** has inferred ***climate change***. Increasing demand to understand this possibility expanded the range of questions to the composition and functioning of the biosphere at large (Tolba & El Kohly 1992; Turner et al. 1987), and ultimately to the meaning of these changes for humankind. Thus, global change and sustainable development have become increasingly fused (Turner 1997), pressuring global change research to become more cogent, relevant, and attuned to policy. Land-use and land-cover change takes on significant meaning in this fusion of research agendas. It is not only an important aspect of global change which is unequivocal and with us now, it is directly related to food security, human health, urbanization, biodiversity, trans-boundary migration and environmental refugees, water quality and more.

Land-cover change may be the most significant agent and medium of global environmental change. It has an important influence on hydrology, climate, global biogeochemical cycles, biodiversity, and structure and function of ecological systems. At the same time, the biophysical feedbacks of these changes, including potential climate change, affect land use. In addition to its role as an input and outcome in global change research, land cover and, by extension, land use is important to study in their own right. Arguably, land-cover change may have a more significant and direct influence on human habitability than climate change over the next 20 to 50 years. It is central to many considerations of sustainability regardless of climate change, although the interactive effects of LUCC and climate change could be the most difficult problems the research community will face.

FIGURE 1-3: Urban Expansion - IKONOS Image of Kowloon, China

And so, land-use and land-cover change is an issue with far reaching policy implications, globally, nationally and locally. Indeed, land-use and land-cover change is as inextricably linked to policy, management, and development as it is to basic research issues.

There is a growing need for global change research to demonstrate its relevance and application to policy. The role LUCC plays in this endeavour is crucial to its own success, and to the successful implementation of global change research. Generally, land-use and land-cover change impinges upon several policy-relevant areas at the global, regional and local scales. The topic of LUCC becomes relevant for the basic research community and for national needs assessments. For example, the monitoring of land cover is vital for improving our understanding of global biogeochemical cycles. Yet, at the same time, such knowledge directly influences policy-making internationally, through such auspices as the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (UNFCCC), or regionally and nationally through national resources assessments such as national forest management planning.

In spite of the growing need for a basic understanding of the process of land-use and land-cover change to support both policy and basic research, an operational programme of measurement, monitoring, and mapping has yet to be developed. Comprehensive and systematic information on the extent and rate of change of forests, wetlands, grasslands, and other land covers is not available on a global basis, despite repeated calls for and demonstrated importance of it. For example, the latest IPCC Third Assessment Report (TAR) considers the rate of tropical deforestation to be one of the key unknowns in global climate change assessment. Any lasting and effective implementation of a global emission inventory to support the IPCC process will require a new, concerted effort to measure and map changes in land cover as well as to understand what drives change in each land cover and region.

At a national level, numerous reports point to the critical need for accurate forest and arid lands monitoring to support forest, grasslands, and desertification management programmes, particularly in developing countries where tropical forests are increasingly important sources of foreign exchange for hardwoods and pulp, and where more marginal arid lands succumb to overgrazing and cultivation. Accurate and up-to-date assessments of forest, grassland, and desertification areas and rates of change are fundamental to the development of improved national programmes of land management. Moreover, issues such as soil fertility and erosion, water yield, water pollution, and land use planning, which are directly linked to development and management of this kind could benefit from such assessments.

Toward an Interdisciplinary Approach: Pathways to Implementation

The global change research community recognizes the critical role of an international and interdisciplinary research approach to problems of the global environment. This recognition is especially true for LUCC, since its understanding requires a cross disciplinary approach, building research around teams of scientists from the physical, social and, in some cases, the policy sciences. Such integration and collaboration is new territory for most global change researchers, and there are but a few proven success stories to guide its development.

LUCC must openly demonstrate its unique mandate for truly interdisciplinary research and, at the same time, be a proven success in doing so. To that end, this *Initial Synthesis* stresses the practical necessity for creating a LUCC research community. First, the programme described here attempts to create a trans-disciplinary approach; integrated LUCC understanding will not be sufficient if problems are engaged separately by social science on the one hand and physical science on the other. Second, LUCC can make substantial progress by building on existing loci of excellence in the field. LUCC related research is emerging everywhere, and it will be important for the programme to identify these emergent groups and gel them together as a framework to expand the community. Lastly, it must be recognized that while the theme of LUCC is

global, it is manifested everywhere on a regional scale. As such, LUCC has a special mandate to engage the regional communities of scientists, not from the top-down, but from the bottom-up. Hence, the development of regional science programmes and networks in close collaboration with organisations such as APN, IAI, START and other region-based groups, is central to its own implementation.

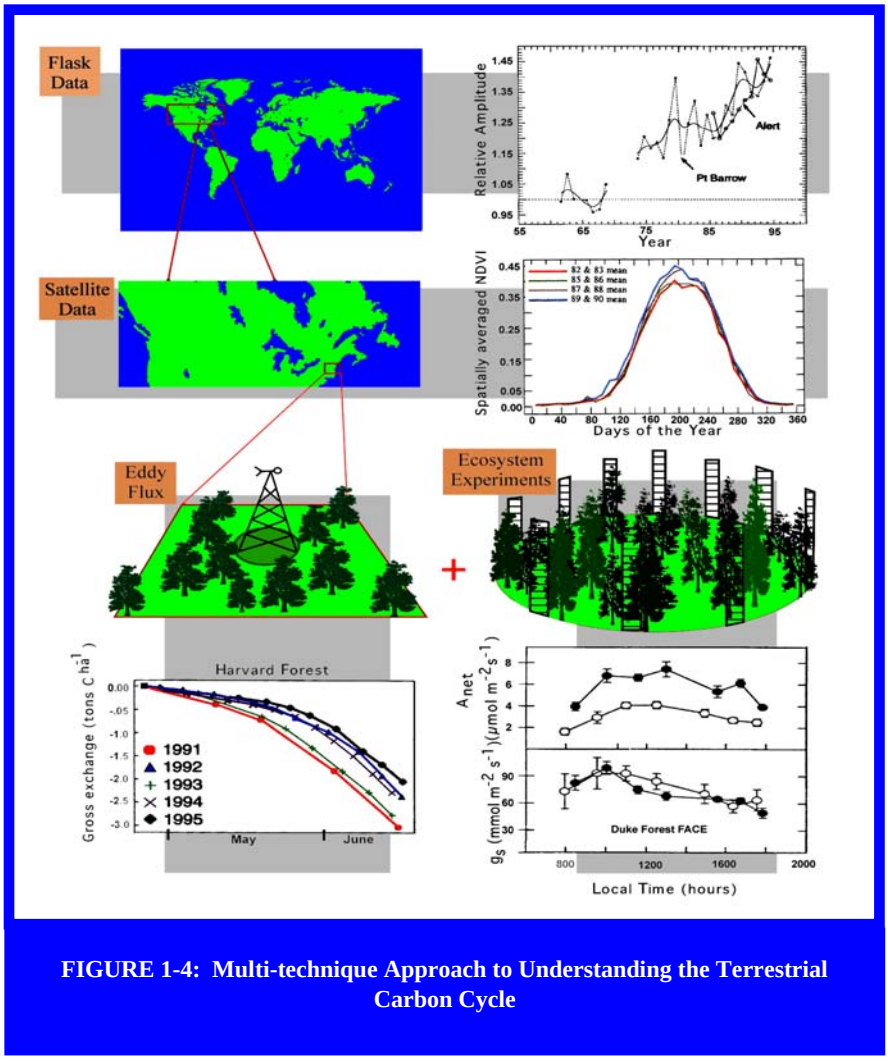


FIGURE 1-4: Multi-technique Approach to Understanding the Terrestrial Carbon Cycle

The long-term goal of LUCC research is a comprehensive and integrative (trans-disciplinary) understanding of the fundamentals of the causes and consequences of land-use and land-cover change and the development of improved means of projecting and back casting land-use and land-cover changes (see Meyer & Turner 1994).

Already, LUCC investigations are underway in a number of regions around the world. Each combines elements of the three basic approaches to understanding what is outlined in the IGBP/IHDP LUCC Core Project Science Plan (IGBP Report #35/IHDP Report #7), even although the aims of the projects differ. Thus, the IIASA-LUC project on Temperate Asia draws upon sub regional data

sets and image analysis to create an integrated regional model for forecasting change. Other projects delve into the underlying social and biophysical dynamics (Foci 1 and 2 of the LUCC Core Project Science Plan) of particular use-cover changes in a region by coupling observations from satellite data of *land-cover change*, with field-based and case-study-based analyses of *land use* processes.

This approach, which is referred to as "Pattern to Process" (Skole 2002) or "Socializing the Pixel" and "Pixelizing the Social" (Geoghegan et al. 1998) may be fundamental to early success because it lays the groundwork from which the integrated models of Focus 3 of the *LUCC Core Project Science Plan* understanding are based. This was the topic of a recent workshop, entitled *People and Pixels* convened by the Committee on the Human Dimensions of Global Change of the U.S. National Academy of Sciences, which brought together the remote sensing, LUCC, and human dimensions research communities to explore this approach.

At the same time, LUCC needs to continue to focus on substantive thematic and policy-relevant issues, some of which are not included in the LUCC Core Project Science Plan. Four such issues will be immediately important:

1. Integrating LUCC and human health, in particular vector borne diseases;

2. Development of LUCC integrative assessments (hence links to policy) beyond the integrated models in Focus 3 of the LUCC Core Project;

3. Establishing vulnerability and impact assessments within LUCC; and the development of observation systems, networks, and approaches for LUCC monitoring; and

4. Development and application of land quality and LUCC indicators, which is also emerging as a major multi-agency initiative of the World Bank, UNDP, UNEP and FAO.

2 Highlights of Accomplishments

APN-funded LUCC research in Asia and the Pacific has resulted in some significant accomplishments. Some of these are highlighted in this section by aligning several examples against each of the APN goals.

Goal 1: Supporting regional cooperation in global change research on issues particularly relevant to the region.

The APN funding of LUCC activities began by funding the development of individual researchers and teams of researchers. Today, this has resulted in a number of ongoing projects and programmes, which involved the collaboration of many scientists in the region, and strong connections to scientists in Europe, North America and elsewhere working with these regional networks.

The SEARRIN network focuses research on drivers of LUCC. Under the direction of Sharifah Mastura S.A. (Malaysia) and her APN-funded project (APN 2001-13), a group of approximately 60 scientists working in teams in Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Viet Nam have been working on case studies and regional analyses of LUCC using geospatial information from remote sensing and ground measurements. They have been examining the drivers of forest cover change using near operational monitoring and numerical models. The results of the research have aided national forest inventories and are contributing to several international observing programmes, such as the United Nations' Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD). The SEARRIN network is now a self-sustaining network, which matches regional funds with APN funds. Groups such as GOFC-GOLD look to the network as the regional framework for their global programmes.

FIGURE 2-1: SEARRIN Science Network - Doi Inthanon, Thailand

The PABITRA network improves understanding of fragile environments. Under the direction of Dieter Mueller-Dombois (USA) this APN-funded project (APN 2002-17) of the Pacific-Asia Biodiversity Transect Network (PABITRA) aims to collaborate with resident Pacific Islanders on biodiversity research and ecosystem conservation. In the project, landscape transect sites are connected to academic and applied research institutions. Local governmental departments and landowner agencies (NGOs) manage these sites in an integrative manner as observation sites or for sustainable use. They are not conservation areas, but are lived-on landscapes subjected to the stresses of global environmental and social changes. Under the guidance of ecosystem research, landscape management now focuses on a balanced and adaptive approach to development. This implies that land-use and land-cover changes are kept in proportion to the islands' sizes, their habitat diversity, and their supply of renewable resources, particularly of fresh water and biodiversity.

FIGURE 2-1: PABITRA Field Biology Training & Joint Analysis Workshop - University of the South Pacific, Fiji

Goal 2: Strengthening the interactions among scientists and policy-makers, and providing a scientific input to policy decision-making and scientific knowledge to the public.

FIGURE 2-3: Training Workshop on Assessment and Modelling of Terrestrial Carbon Stocks

The SEA-SPAN Network translates LUCC-carbon science into policy. Under the direction of Daniel Murdiyarso (Indonesia) and his APN-funded project (APN 99004), a LUCC-carbon research network has been formed, which couples active research to capacity building, impact assessments and policy support. This network involves several institutions in Indonesia, Malaysia, Philippines and Sri Lanka. Results from this project suggest that:

- The inventory of below- and above-ground biomass of various land use types in participating countries that may be converted into terrestrial C-stocks and their rates of change;
- Emissions of GHG from soils in the changing land use and land cover; and
- The roles of ecosystem disturbance such as fire on the dynamics of terrestrial C-stocks.

This project has been focused on network capacity building in three areas of:

- Training workshops;
- Commissioned reviews; and
- Science-policy workshops.

The effort has resulted in the Southeast Asian Science-Policy Network (SEA-SPAN), which actively provides input into the Kyoto Protocol and the IPCC process, and engages regional scientists in the science and policy aspects of the issue.

Goal 3: Improving the scientific and technical capabilities of nations in the region

Spatial data and information is being used for land use and forest management. Under the direction of David Skole (USA), and his APN-funded project (APN 2001-09), information derived from space based remote sensing and other geospatial information management technologies is being deployed to provide support to natural resource managers who need to evaluate the amount of forest cover and how it is changing under pressures from land-use change. The aim of the project is to focus on "global change at scales that matter" by translating the results of global change research into practical applications. Using scientists in the SEARRIN network, this project is transferring technologies for mapping forest density, a parameter

FIGURE 2-4: Field Training in Doi Inthanon National Park, Thailand. Use of LI-COR LAI-2000 and Fish-Eye for *in-situ* Forest Canopy

important to both carbon models and forest inventory and management, through collaboration with the forest and resource management agencies in the region. The project aims to deploy in Southeast Asia some of the concepts and approaches being developed under the initiative on "geographic information for sustainable development" which was introduced in a National Academies report and adopted at the World Summit on Sustainable Development (WSSD). This project represents the coupling of network capacity building (i.e. SEARRIN) with basic global change science and practical applications.

Goal 4: Facilitating the standardization, collection, analysis and exchange of scientific data and information relating to global change research

Land-use change and carbon accounting. Under the direction of Josep Canadell (Australia) this APN-funded project (APN 2000-02) has examined the procedures for measuring carbon dynamics and developing a system of accounts for carbon emission accounting. The project has reviewed accounting and reporting requirements under the Kyoto Protocol, current knowledge and advances in measurement technologies and research needs and defines key research issues derived from science and policy needs, as well as a coherent and integrated research and funding strategy for the region. The project also involved an initial workshop and a commissioned study.

Goal 5: Cooperating with other global change networks and organizations

Land use systems in Temperate East and Central Asia. Under the direction of Chuluun Togtohyn (Mongolia) and Dennis Ojima (USA), this APN-funded

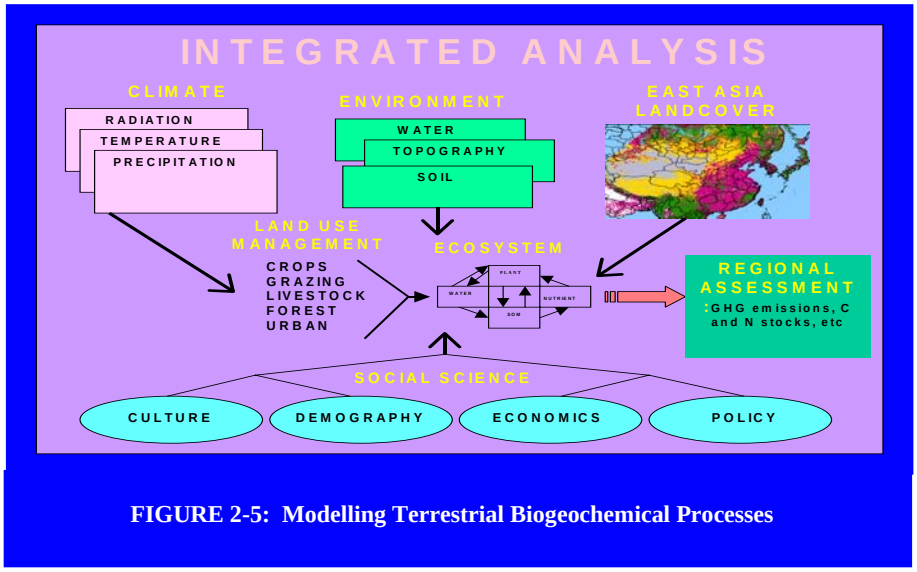


FIGURE 2-5: Modelling Terrestrial Biogeochemical Processes

project (APN 2001-03) developed very close working ties between the SARCS and TEACOM regional networks of START. The work focused on the full range of APN goals, including the development of advanced remote sensing

monitoring of inter- and intra-annual greenness for the assessment of forage and range quality, support to sustainable management of rangelands, and networking and capacity building. The project provided fora for regional and international scientists to share information and develop a stronger understanding of linkages between climate, ecosystems and human elements of the region. The project also facilitated the integration of the knowledge gained by different research groups of natural and social scientists, and identified policy products and knowledge gaps.

Goal 6: Facilitating the development of research infrastructure and the transfer of know-how and technology

Science-based impact assessment of land-use change. Under the direction of Kedar Lal Shrestha (Nepal) this APN-funded project (APN 2001-17) has been enhancing decision-makers' abilities to accurately assess the environmental impact of land-use change in fragile mountain landscapes. The results of the analysis are expected to produce scenarios on the potential

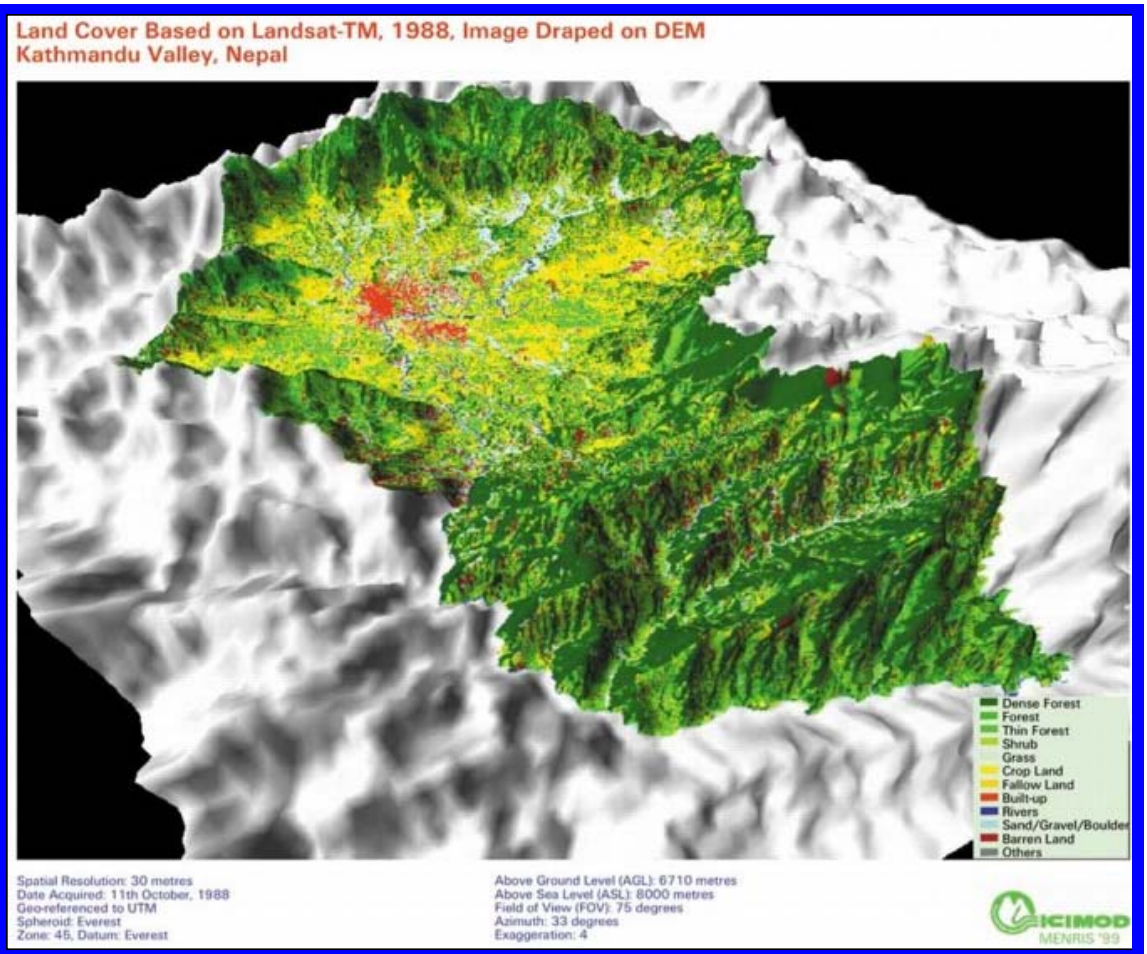


FIGURE 2-6: Use of Remote Sensing and GIS for Land Cover Analysis in Nepal

impacts of global change and anthropogenic cumulative change, and a policy framework for monitoring systems and response strategies to address the impact issues for sustainable development. Information regarding the key findings will be distributed to planners, policy-makers and decision-makers.

3 Impact of APN-funded Land-use & Land-cover Change Projects

The APN has funded several land-use and land-cover change related projects which, when viewed collectively, form an impressive array of research. This section provides an overview of APN's current LUCC agenda by detailing the funded activities, and sets a foundation for recommendations for future efforts.

Interactions between land-use and land-cover change and the Carbon Cycle

Participants

30 participants from Australia, Indonesia, Japan, Malaysia, Mongolia, The Netherlands, Philippines, P. R. China, Republic of Korea, Russia, Thailand and USA.

Rationale

Land use and cover type is an important control of carbon storage, and shifts from one type to another are responsible for large carbon fluxes in and out of the terrestrial biosphere. Historically, land use emissions have been responsible for 180-200 PgC (1 Pg = 1 million tonnes) and current emissions are estimated to be 1.6 PgC yr^{-1}.

The increasing attention to carbon emissions and other greenhouse gases is because of the link to the mean increased global temperature of 0.5°C over the last century and other changes in climate patterns and variability. A good understanding of the carbon sources and their magnitude is the basis for developing strategies to reduce emissions and promote practices that may

BOX 1: Land-Use and Land-Cover Change and the Terrestrial Carbon Cycle in Asia

Annual emissions of carbon dioxide from land-use change and forestry are about 25% of the total global carbon emissions. However, Non-Annex 1 countries under the Kyoto Protocol, and particularly tropical countries, account for the largest fluxes due to land-use change (e.g., Southeast Asia alone accounts for about 50% of the global carbon emissions from land-use change). Therefore, it is fundamental to understand the impacts and causes of land-use change on terrestrial biogeochemistry and particularly carbon as a greenhouse gas and as an emerging new commodity.

increase carbon uptake.

Major findings

- Land-use change emissions from tropical Asia have stabilized towards the end of the 90's in an all time high above 1.0 PgC yr^{-1}.
- Natural forest in Southeast Asia contain up to 500 MgC ha^{-1}, logging activities and conversion to other tree plantations are responsible for at least a 50% decline in forest carbon density; conversion to grasslands and crops are responsible for up to a 90% decline. A whole list of carbon density changes owing to multiple land-use and land-cover changes in Southeast Asia have been reported.
- 60% of the carbon in rivers occurs in tropical regions. Land use degradation is responsible for 0.24 PgC yr^{-1} being transported through multiple tributaries in a single basin in India.
- About two-thirds of the mechanisms invoked to explain the current Northern Hemisphere mid-latitude carbon sink are related to current or the legacy of past land use practices. This includes reforestation, forest re-growth, and changing logging rotation terms in Japan, P. R. China, Republic of Korea and Russia.
- Moving to a 70-yr forest rotation in Japan would allow for an accumulation of 16 MtC yr^{-1}, which is equivalent to removing 4% of the annual fossil fuel emissions from the atmosphere.

Significance

Globally, the results presented above will improve the estimates of carbon sources and sinks, and their strength and location. This is a critical step to further understand the linkage between the human perturbation of the carbon cycle and the effects on climate change as required by the UNFCCC.

Regionally, an improved understanding of the carbon consequences of land use practices will allow for the design of better strategies for reduced carbon emissions (via best management practices) and increased carbon uptake (e.g., reforestation). This new understanding will feed information directly to the requirements of the Kyoto Protocol. The reported information will help with compliance strategies for developed countries (Annex 1 countries) and base knowledge for participating in the Clean Development Mechanism (CDM) and other carbon trading activities for developing countries.

Links to APN goals

Goal 1: The research presented here has shown that the region is the largest contributor of land use CO_2 emissions into the atmosphere in the world and, therefore, has identified the issue as one of the highest priorities for the region.

Goal 2: Measurements of carbon emissions and possible carbon sequestration potential due to different land use practices provide critical information required for policy-makers to assess the feasibility of sequestration projects. This knowledge can bring important business

opportunities to countries that can demonstrate they have the capabilities to ensure permanency of the sinks and verification tools.

Goal 3: This APN project supported the development of new research proposals that are now fully funded at a level many times higher than the initial investment by APN.

Goal 4: This project made a major effort in synthesizing available state of the art information on the topic which is posted over the Global Change and Terrestrial Ecosystem (GCTE/IGBP) website <http://gcte.org/>. In addition, an equal effort was made to ensure the proper quality of the results and dissemination among the research community in Asia and the rest of the world by publishing a peer reviewed special journal edition on the topic. Peer review ensures high standards of the publication and accessibility around the world by being published in English and in standards accepted by the International Current Contents of peer-reviewed journals.

Goal 5: This activity has contributed to the global research agendas of the GCTE Core Project of IGBP, the LUCC Core Project of IGBP/IHDP, and the new DIVERSITAS-IGBP-IHDP-WCRP (ESSP) Global Carbon Project. All products and relevant information has been disseminated by these international projects.

Goal 6: This project assisted a number of countries led by Mongolia and the Philippines to develop successful multi-nation proposals for the GEF-IPCC programme on AIACC.

Recommendations for future research

- Groups working on detection and measurements of land-use and land-cover change need to work closer together with groups working on the impacts that brought about those changes. It is not always the case that land-use changes measured are the ones that are most needed for impact studies. Not all impact studies require the same type of land use and land cover measurements, for example, the set of critical land-use and land-cover change categories needed for studying impacts on biogeochemistry (e.g., carbon or nitrogen), may be a little different from those needed to study impacts on biodiversity or water availability. That is why we need to ensure that detection and impacts are developed under a common umbrella that allows for the necessary coordination between the two communities largely associated with different research disciplines.

- Although the first step is outlined above, land-use and land-cover change needs to be much better integrated under the paradigm of "*causes, detection of change, impacts, and responses.*" This is a loop whereby a number of internal and external forces are causing land-use and land-cover change to take place, with impacts on critical

ecosystem services for human welfare. Human perceptions of a problem gain results in institutional and human responses that feed back on the causes of those changes and is, therefore, changing the course of the changes and subsequent impacts. This is the paradigm that should guide future research on land-use change under the APN allowing for the full integration of biophysical and human components.

Land-use and Land-cover Change as related to C-Stocks: Capacity Building, Impact Assessments, Policy Support in South and Southeast Asia

Participants

The participants of the entire activities, which included planning workshops, training workshops, science-policy workshops and commissioned reviews, may be categorized into three groups:

- Academia (both senior and junior),
- Government officials and the business community, and
- NGOs.

In total, the activities involved more than 100 people.

Rationale

The project was designed around scientific and policy questions on the dynamics of LUCC and its implications on terrestrial carbon and trace gases. It was also realized that interaction among stakeholders' needs to be facilitated so they can fully participate in national programmes related to sustainable development and are ready to take part when international agreements and treaties like the UNFCCC and the Kyoto Protocol become operational.

The project had three main components: capacity building, impact assessment, and policy support with the overall objective to bring global change science into public policy-making processes, especially in understanding the role of terrestrial carbon in climate change.

Major findings

- Inventory of below- and above-ground biomass and carbon density of various land use types. The inventory ranges between 2 tC/ha (*Imperata* grassland) and 390 tC/ha (lowland Forest).
- Emissions of GHGs from soils with changing land use and land cover. CH_4 absorption ranged between 5 $\mu g/m^2/h$ (*Imperata* grassland) and 38 $\mu g/m^2/h$ (jungle rubber). N_2O emissions were relatively low (below 10 $\mu g/m^2/h$), except in fertilized oil palm plantations where it reached almost 400 $\mu g/m^2/h$. Meanwhile, CO_2 emissions were approximately 600 μg/m2/h and did not substantially vary between land use types.

- The role of ecosystem disturbances such as fire on the dynamics of terrestrial C-stocks is highly evident. For example, the 1997 "big fire" was estimated to remove more than 7 MtC in 190,000 ha of Berbak National Park in Jambi, Sumatra.

Significance

It was understood that the removal of forests by clear felling or slash-and-burn practices would result in decreased C-stocks by as much as three orders of magnitude. The outputs of the activities will significantly contribute to the understanding of the interactions between humans and their biophysical environment. Changes in land use and land cover, which were quantified in terms of C-stocks and biogeochemical cycles, will provide an insight for the policy community and resource managers to make decisions that address the concerns of stakeholders.

Land use and land management is a major agenda item in the area of sustainable development for many developing countries. In reality there are several options between maintaining forest (carbon) and developing land to meet sustainable development objectives. Land use decisions following complete and incomplete removal of forests may be weighted with sound scientific basis as far as sustainable development objectives are concerned. Deforestation is not a binary choice between forest and non-forest. The development of timber and oil palm plantation, or practicing simple or complex agro-forestry are among the options that can be considered where trade-offs and supplementary aspects may be demonstrated.

Policy implications

The activities are highly relevant to policy-making processes as far as the local, national and global agendas are concerned. Therefore the current understanding on the dynamics of LUCC may be brought into the policy arena for three reasons to:

- Increase the awareness of the policy community of the importance of terrestrial carbon in the global carbon budget;
- Strengthen their capacity in policy that addresses the concerns of the local community and national interests; and
- Improve their confidence in the negotiation processes related to climate change and the roles of terrestrial ecosystems, particularly forests, as a source and sink of carbon.

Links to APN goals

The activities brought scientists and policy-makers in the participating countries (Indonesia, Malaysia, Philippines and Sri Lanka) together to build meaningful co-operation through interactions and the sharing of knowledge, challenges and opportunities in the domain of LUCC, but with a more specific relation to terrestrial carbon.

BOX 2: Measuring Greenhouse Gas Emissions in Jambi, Sumatra, Indonesia

GHGs flux measurements for three major trace gases (CO_2, CH_4, N_2O) were conducted on five land cover types: natural lowland forest, jungle rubber, 1-year and 6-year old oil palm plantations, and *Imperata* grassland in Jambi Province, Sumatra, Indonesia. The measurements were carried out at plot level and extrapolated to represent the entire landscape where massive land-use change is presently observed. Forest conversions are taking place for large-scale oil palm plantations. At the same time there is the local practice of *sisipan*, a type of rubber agro-forestry or "jungle rubber" farming, in which local people do not clear cut old growth forests but plant rubber seedlings where canopy gaps are found. Farmers with large areas and adequate resources are more successful with *sisipan*. Others, though, tend to clear forests completely using fire, leading to loss of soil fertility and the invasion of *Imperata* grass. The study showed (1) CO_2 emissions from removal of above-ground biomass is more significant than from soil which does not show significant difference across land use types, (2) Logging causes significant increases in N_2O flux but the flux rate of Southeast Asia soil is half that of Latin America, and (3) Intensified land use oxidizes less CH_4.

Recommendations for future research

Land-use and land-cover change and climate change are relatively new issues in our society. Their complex interplay needs scrutiny before the cause-effect chain is well understood. Policy-makers and resource managers are often confronted with difficult options when sound information is not available. It is important, therefore, to design a research agenda that is policy relevant.

This project has created a great number of lessons since the inception of the activities until the dissemination of the results. Both the scientific and policy community face enormous problems of uncertainties from their own perspective. The fact that such uncertainties and gaps were significantly reduced and more focused when interactions took place, was clearly noted.

It is recommended that:

- Criteria and indicators for sustainable development need to be developed.
- Impact assessments of forest carbon projects should be based on sound science.

Participants

Participants in this project included members of SEARRIN. SEARRIN is a formal network of over 50 scientists from academic, government and non-government organizations. Institutions and agencies represented include:

- Cambodia: Ministry of Environment;
- Indonesia: BIOTROP Information Center (BTIC), BPPT-TISDA, LAPAN;
- Lao PDR: National University of Laos, Laos Forestry Department;
- Malaysia: EOC-UKM, Malaysian Forestry Department, MACRES
  Philippines: NAMRIA, PAGASA, NEDA, UP-Diliman;
- Thailand: GISTDA, Mahidol University, CM University, Kasetsart University, RFD, Land Development, NRCT, etc.;
- United States: Michigan State University, NASA, UMD; and
- Viet Nam: Hydro-Met, FIPI, CRES.

Rationale

Significant advances in the analysis of remotely sensed, earth observation data and geographic information systems provide an opportunity within Southeast Asia to develop assessments of land use and forest cover, in qualitative and quantitative terms, both spatially and temporally, to support local, national and regional management programmes and policies. Specifically, the application of fractional cover or continuous fields assessments derived from remotely sensed data can help regional scientists and natural resource managers answer questions related to forest degradation and quantify forest biophysical properties over large areas. Operational monitoring using direct observations over large areas with fine resolution satellite data (1) can augment costly and time consuming *in situ* measurements of traditional forest inventory assessments, (2) can provide accurate primary data related to conservation and biodiversity issues, and (3) can assess the efficacy of natural resource management initiatives and policies (e.g. encroachment of illegal logging in protected areas or community-based reforestation projects in critical watersheds). In parallel with the remote sensing and GIS technical advances are the improved capabilities related to spatial data support systems that allow for the development of online, Internet-based applications providing users (scientists, policy-makers and natural resource managers) access to geospatial data and information.

Findings

The current state of the science of remote sensing analysis can provide accurate, geospatial, empirical data from direct observations beyond discrete classifications. Fractional cover analysis of forest cover can detect disturbed and degraded forests where traditional land cover classifications have failed. Furthermore, this research shows that there are strong correlations between forest biophysical properties measured through *in situ* methods and fractional

cover analysis at the fine-resolution scale. These calibration and validation case studies advance global change science with respect to using remote sensing techniques to measure land cover as inputs to understanding carbon budgets, the impacts of land-cover change and degradation on biodiversity, and furthering our knowledge of human dimensions "driving" these changes. The data users within SEARRIN recognize the potential of these methods and products to support local, national and regional needs with regard to operational monitoring and assessments.

Significance

- ***Research***: While valuable scientific information has resulted from the analysis of remotely sensed data, the contributions to LUCC have at times fallen short. Comparisons of data from different projects suffer from differing definitions of land cover and land use types and from different methodologies. The use of sub-pixel linear un-mixing algorithms applied to remotely sensed data provide a standard method to quantify forest cover beyond discrete classifications that are often non-existent in reality and which can assess degradation in forest areas previously undetected.

- ***Policy***: It is preliminary to assess the significance of the research in terms of policy implications. However, SEARRIN participants (many of whom are users of data themselves and who work in national agencies directing policy) have acknowledged the utility of such data products to assist in monitoring forest resources, in assessing policy efficacy (bans on logging and the status of forests within protected areas), and for developing resource development programmes (e.g. timber valuation assessments).

Links to APN Goals

This project links explicitly to the APN goals 1, 2, 3, 4 and 6 and indirectly to goal 5. The implementation of this project by the SEARRIN network on land use and forest cover included seven regional teams. Members of these teams come from both the science (university and national technical ministries or departments) and the policy (forestry departments and natural resource management ministries) communities (goals 1, 2 and 6). Assessments of forest fractional cover in five case studies in five different countries used the same protocol and methods for analysis, validation and calibration (goal 4). Two training workshops included over 30 scientists from all seven regional SEARRIN countries (goals 3 and 6). The development of the SEARRIN-DISS, Internet-based web applications are part of data infrastructure providing open access to geospatial data (goal 4). SEARRIN is a recognized network for the UN-led GOFC/GOLD programme and has also participated in developing a sub-regional proposal for the MA. SEARRIN is also tied directly to START SARCS and the IGBP/IHDP LUCC Core Project (goal 5).

BOX 3: Forest Fractional Cover Measurements for Natural Resource Assessment and Management

Degradation and impoverishment of forests by deforestation, selective logging and other factors can be indicated in biophysical properties such as leaf area index, total above-ground biomass, and the ability to absorb photosynthetically active radiation. These properties are also important characteristics of forest for carbon sequestration and are critically needed for modelling energy and carbon fluxes. Forest density can be viewed as having two components: a horizontal or spatial component, and a vertical component through the canopy. Fractional cover (*fc*) assessments can be used as an indicator of forest density. By definition, *fc* is the fraction of area occupied by trees per unit area. For mature forest, *fc* would be 100% while for clear-cut forest *fc* would be 0%. Unlike traditional classification techniques, which classify a pixel either as forest or non-forest, *fc* is a continuous variable that characterizes "how much" is forest or trees. Therefore, *fc* can be applied to an entire area to quantify how much of that area is occupied by forest, or applied to a single pixel to indicate the percentage area being occupied by trees. This indicator specifies "how much" an area is occupied with trees/forest, but does not indicate "where" they are. Nevertheless, *fc* is a general indicator of forest density of lateral tree distribution. It complements leaf area index measurements, which are a more vertical distribution of leaves or branches. In addition to being an indicator of forest density, *fc* can also be used in many cases as a forest health indicator such as forest fragmentation and as a measure of forest disturbance.

The fractional cover of forest or trees can be estimated from remotely sensed imagery using a linear mixture model (LMM). This model assumes that a pixel is a result of the contribution of two components: forest and soil/litre substrate. The fractional cover of the forest is *fc* and therefore the substrate is 1–*fc*. The resulting signal, S, as observed by a remote sensor can be expressed as:

$$S = fc \times Sv + (1 - fc) \times Ss,$$

where *Sv* is the signal contribution from the forest vegetation component and Ss from the substrate. When applied in the reflectance domain (Maas, 1998), this equation was used to successfully estimate cotton percentage cover. When used in vegetation index domain (Zeng et al., 1999, and Qi et al., 1999), fractional green vegetation cover was mapped at different spatial scales.

Recommendations for future research

Basic research is still a priority in LUCC and global change research. Rapid technological advances drive new innovative research with respect to remote sensing and GIS contributions to LUCC science as well as to fostering collaborative open sharing of geospatial data and information. The recommendation here is to fund projects where scientific analyses can lead to the development of policy-relevant data and information.

Interactions between LUCC Dynamics and Model Analyses (SEARRIN)

Participants

Participants in this project included members of SEARRIN. SEARRIN is a formal network of over 50 scientists from academic, government and non-government organizations. Institutions and agencies represented include:

- Cambodia: Ministry of Environment;
- Indonesia: BIOTROP Information Center (BTIC), BPPT-TISDA, LAPAN;
- Lao PDR: National University of Laos, Laos Forestry Department;
- Malaysia: EOC-UKM, Malaysian Forestry Department, MACRES;
- Philippines: NAMRIA, PAGASA, NEDA, UP-Diliman;
- Thailand: GISTDA, Mahidol University, CM University, Kasetsart University, RFD, Land Development, NRCT, etc.;
- United States: Michigan State University, NASA, UMD and
- Viet Nam: Hydro-Met, FIPI, CRES.

Rationale

To investigate the inter-annual dynamics of deforestation, re-growth and land-use and land-cover change in the Southeast Asian region using remote sensing and GIS, and relating it to the driving forces of land-use and land-cover changes from the socio-economic aspects in selected study sites throughout the seven participating countries. Models developed are used to improve the understanding of the causes of deforestation.

Findings

Forests have been converted to agricultural lands, urban and settlement areas, water bodies and recreational areas and other land use categories in most of the selected sites. Human activities and population dynamic variables such as the population diversity, literacy rates and road networks are the dominant underlying forces of these changes. The results show that population dynamic variables explain 54.5% of land-use change in the four countries, combined agriculture and economic variables account for 18.2% and economic variables for 13.6%. Other significant variables are policy, 9.1%, and road networks, 4.5%. Empirical findings of LUCC research show that there is no single variable that can explain the causes of deforestation. The factors are few and most frequently interrelated. The results show that for this study, the combined factors are population dynamics, roads, agriculture, and economics. They are all driven by policy, institutional and cultural factors combined. Forest loss is the most significant land-use change in most sites. The causes attributed to LUCC are multivariate in nature, interrelated, and differ at local, national and regional scales.

Significance

The LUCC mapping adopted in this APN-funded research only detected the dominant features for each category and did not indicate multiple land use, which is sometimes common in tropical areas. Forests, for example, are mapped as a discrete class without further indication of their density and maturity, which are important inputs to the study of sustainability science. To further improve on the value of the information system, the research network has already initiated selected sites within the region to carry out fractional forest cover mapping. Fractional forest cover mapped an image pixel as a continuous field variable that characterized how much of the pixel is actually forest. In the field, these derived estimates can be validated by measuring the canopy closures. Thus, fractional

forest cover mapping improves further the quality of LUCC data. Such data can be linked to forest biophysical parameters, which are a vital input to forest resource management.

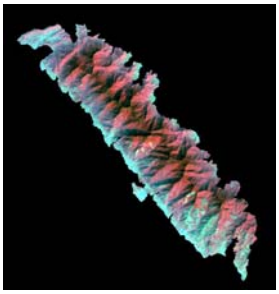
The case study approach should be scaled up to a multi-date, wall-to-wall coverage for the whole country and the Southeast Asia region. Full-scale coverage would certainly be very useful to the decision-makers as the information would strengthen each country's national capacity to assess its national resources systematically as well as to monitor environmental change arising from land-use change. The Southeast Asian countries can participate effectively in international agreements and conventions.

BOX 4: Efficacy of National Policy - Forest Protection and Re-Growth in Tamdao National Park, Viet Nam

Tamdao National Park (TDNP) is located in three provinces northwest of Hanoi (Vinh Phuc, Thai Nguyen and Tuyen Quang). The park was established in 1996, in order to protect its rich and diverse forest resources and promote sustainable natural resources management. Forests in TDNP can be classified under tropical forest with a predominance of species of *Dipterocarpaceae* and *Lauraceae*. However, in the TDNP, for the high degree of differentiation of humidity and altitude there is very diverse flora, including not only tropical and sub-tropical species but also species of a moderate zone. There are the following Gymnosperm species in the park: *Amentotaxus* sp., *Fokienia hodginsi*, Yen Tu *pinus* (*Podocarpus brevifolius*) and *Podocarpus fleuryi*. *Fokienia hodginsi* is a moderate zone species distributed at an altitude of 1,000 m and higher. In Dai Tu district (Thai Nguyen province) at an altitude of 1,000 m, *Fokienia hodginsi* grows in large patches, in combination with other broad-leaved species. In the TDNP there are the following forest types:

- Evergreen tropical rain forest;
- Evergreen sub-tropical rain forest in mid mountain altitudes;
- "Short" forest at the mountain top;
- Secondary forest after over logging;
- Regenerating forest; and
- Forest plantation.

Remote sensing analysis of Landsat data acquired in 1975 (MSS), 1992 (TM), and 1999 (ETM+) using supervised isodata clustering showed an increase of more than 12,000 ha (89.9%) in secondary growth forest cover between 1975 and 1999. The period between 1992 and 1999 saw a decrease in both open land and agriculture, which is a positive effect on land use management and forest cover since the park's establishment.



Tamdao National Park

Links to APN Goals

This LUCC project is a high priority project in global change research. SEARRIN is very active in this area and has significantly contributed to identifying change areas, drivers of change and rates of change. This is a significant contribution to one of the important global change issues. The SEARRIN network, which was established under APN funding, consists of more than 50 scientists from 7 countries. SEARRIN made available its products to LUCC users that include policy-makers. SEARRIN scientists contribute to capacity building in global change research in the Southeast Asia region. SEARRIN infrastructure supports the standardization, sharing and exchange of scientific data. SEARRIN scientists are actually involved in GOFC/GOLD, the IGBP/LUCC Core Project, ICSEA and START-SARCS.

Recommendations for future research

1. The case study approach should be scaled up to a multi-date, wall-to-wall coverage for the whole country and the Southeast Asia region. Full-scale coverage would certainly be very useful to decision-makers as the information provided would significantly strengthen each country's national capacity to assess its national resources systematically as well as to monitor environmental change arising from land-use change.

2. The LUCC classification system adopted in this study has been developed independently within the network to suit the region's requirement. Standard systems such as the Land Cover Classification System (LCCS) formulated by the UN-FAO would have an advantage for comparison purposes and should be adopted.

3. Research results and experience from the APN project will provide a foundation for SEARRIN to pursue future projects in global change research. The network should be active in other projects such as the:

    - GOFC-GOLD Programme, which is a collaboration of the space agencies, IGBP/IHDP and other participants in the Global Observing Systems. Research on forest fires and the classification of burned forests will develop the methodologies to characterise the regional spatial pattern occurrence in Southeast Asia by combining climatic and biophysical parameters with the human dimensions of land use.

    - Millennium Ecosystem Assessment (MA) [2], which has been developed to improve the management of the world's natural and managed ecosystems.

    - UN-FAO project on AsiaCover in this region, with the objective of developing a land use map, digital database and statistics based on existing land-cover information to facilitate regional cooperation for

[2] APN is currently funding an MA Sub-Global Assessment Project (APN 2003-10).

food security, sustainability and environmentally sound agriculture in Southeast Asia.

Change and Sustainability of Pastoral Land Use Systems in Temperate East and Central Asia

Participants

40 international and 60 Mongolian participants attended the Symposium. Participants from Australia, Japan, Republic of Korea, Russia and USA were directly funded by APN. Participants from Kazakhstan, Uzbekistan and France were sponsored by MEDIAS-France in order to allow scientists from Central Asia to set up a regional network and have contacts with their colleagues from the LUTEA project[3]. START supported TEACOM members, and some participants from Australia, France, Germany, Kazakhstan, Russia, UK and USA were self-funded.

Rationale

The rationale behind the Symposium on Change and Sustainability of Pastoral Land Use Systems in Temperate East and Central Asia was to gather international and local multi-disciplinary experts who did long-term research primarily on pastoral land use systems in the region. The Symposium provided a forum for regional and international scientists to share information and develop a stronger understanding of linkages between climate, ecosystem and human elements of the region. The Symposium facilitated the integration of the knowledge gained by different research groups of natural and social scientists, and identified policy products and knowledge gaps.

Findings

Pastoral land use systems occurred as an emergent property of nature in arid and semi-arid lands of the world. A rapid change in pastoral land use systems has occurred in all countries of East and Central Asia with transition to a market economy and democracy during the last decades. A diversity of responses to political and environmental shocks happened in different countries of this region. It is likely that the change in pastoral land use systems will only intensify with population growth, globalization and climate change. A critical question is: *How can we develop these pastoral societies socially and economically while conserving their internal coping mechanisms with uncertainties?*

Significance

Delayed plant green-up with warming has been found in some parts of the Mongolian Steppe (Ellis *et al*., 2001). This has adverse implications to previous research established that warming trends in high latitude environments are causing longer growing seasons, increases in photosynthetic activity, and greater CO_2 uptake. These changes would certainly be viewed as negative for the herbivores and humans that depend

[3] APN has since funded an International Workshop on Global Change, Sustainable Development and Environmental Management in Central Asia (Tashkent, 20-22 January, 2004).

on high latitude grassland/steppe environments for their sustenance and support.

Recommendations for future research

Where are the most vulnerable regions to climate and land-use changes? Impact, vulnerability and adaptation assessments of land systems to climate change are critical for regional sustainability. Identification of vulnerable regions and thresholds where climate change and land-use and land-cover change would interact through feedback could be an important future direction of land research in conjunction with the IPCC activities on vulnerability and adaptation to climate change assessment research. The cooperation of natural and social

BOX 5: Fundamental Issues Affecting Sustainability of the Mongolian Steppe

In arid and semi-arid regions of East and Central Asia, nomadic pastoralism has been the dominant agronomic activity for many centuries. Recent political, economic, social and cultural factors have caused dramatic changes in pastoral land use systems. A diversity of responses to political and environmental shocks occurred in many countries of this region resulting in changes in natural resource use.

In Mongolia the risk of climate change and/or extreme climatic events could have dramatic impacts on the economy and natural systems. Particularly vulnerable is the rangeland and livestock sector, which occupies about 80% of Mongolia's territory. As land use intensity and the frequency and magnitude of climate variability rise, the resilience and adaptive capacity of traditional networks and land use systems to cope with climate variability/extremes weaken. This project aims to comprehensively assess the impacts, vulnerability, and adaptive capacity of the rangeland and livestock sector in Mongolia to climate change. Impacts will be evaluated through the quantitative and qualitative estimation of potential productivity under different climate change scenarios. A combination of ecosystem modelling, remote sensing data, analysis of existing long-term plant dynamics and climate databases, and field surveys will be used to investigate climate and land-use change effects on grassland ecosystem structure and function. Particular priority will be placed on the study of interactions between climate, grassland and pastoral systems, and social institutions in order to assess vulnerability and adaptive capacity of the integrated system and ultimately support environmental planning and decision-making.

scientists for this assessment is still an important issue in the region where traditionally such collaboration was undermined.

How can we integrate conservation of the complexity of the human-environmental systems in ASALS with the globalization/development process?
A future multi-disciplinary study of the human-environmental systems in arid and semi-arid lands of East and Central Asia should be carried out in close collaboration with stakeholders and policy-makers. Conservation, rural and regional development would be successful if it was culturally acceptable, and economically and socially viable.

How can we support global change research in developing countries?
One important change in the APN policy could be to give more research opportunities to scientists from developing countries on global environmental change issues identified by the local governments and which fit the goals of the APN because the governments of developing countries often do not have adequate funding for global change research.

Global Change Impact Assessment for Himalayan Mountain Regions for Resource Management and Sustainable Development

Participants
The Scoping Workshop was held in Kathmandu from 2-5 October 2001 on 'Global Change Impact Assessment for Himalayan Mountain Regions for Environmental Management and Sustainable Development.' Approximately forty participants from Nepal, India and Pakistan took part in the workshop including representatives from the APN and the Mountain Research Initiative of IGBP. In the first two days of the workshop, during the four Technical Sessions, about 20 papers by various speakers were presented dealing with various aspects of global change issues in the Himalayan Mountain region, including some country presentations. During the Scoping Workshop, in the remaining two days, participants deliberated in particular on the regional project proposal submitted earlier to APN for funding on the topic of the workshop. In the course of the deliberations, the need and importance of such a study focusing specifically on the Himalayan Mountains and the mountain people was recognized. Climate change and variability, demography and land use intensification were all identified as some of the major driving forces causing stress to human society.

Rationale
LUCC in Himalayan Mountain areas: Over 90 million people and nearly 60 million livestock inhabit the Himalayan Mountains that extends over 2,400 km and covers an area of over 460,000 sq. km. The Himalayan Mountains are extremely rich in biological and cultural diversity and are inhabited by traditional societies facing serious threats of environmental degradation. The Himalayan Mountains are young and fragile, and undergoing natural and anthropogenic land degradations. The increasing population pressure in the mountain regions has contributed to major changes in land use and land cover patterns. Growing

demands for firewood, fodder and timber are all leading to rapid deforestation in the mountain regions. In Nepal, between 1978 and 1985, forestland was found to have decreased by 0.25% per annum.

The extensions of agricultural to forest land and even to marginal lands are other noticeable land-use changes in the mountain regions. Likewise, the degradation of forest due to excessive extraction of fodder for meeting the needs of the livestock are other negative impacts on the land cover observed in the mountain areas.

Major Findings

Impacts on Hydrology: The Himalayan Mountains trigger orographic precipitation and influence the South Asian Monsoon. They act as a water tower to over 1 billion people living in the southern plains and provide over 500 billion cubic metres of annual river flow. The consequent land erosions and landslides due to the loss of vegetation cover of the surface are causing heavy sedimentation flows leading to surface rise and floods in the downstream regions. Annually, over 1.7 billion tonnes of sediments are carried over from the mountains down to the plains. Furthermore due to the reduced water holding capacity of the soil and the reduced underground water storage potentials, the water flow patterns are changing with higher run off during the rainy period and drying of the springs and wells during dry periods.

BOX 6: Impacts of Global Climate Change on Himalayan Glaciers

Change in snow content and snow cover on the high Himalayas are reducing the water storage as well as water flow regulatory potentials of these high mountains, causing decreased river flow in snow fed rivers during dry seasons when the water demand for crops and people is rather high. The glaciers during their retreat cause formations of glacial lakes bounded by unconsolidated moraines that with the rise in water level suddenly gives way causing what is known as Glacial Outburst Floods (GLOFs). These GLOFS are causing growing hazards and hence are drawing growing concerns

Studies have shown that the glaciers in most parts of the Himalayan peaks are retreating fast due (evidently) to global warming. About 3 million hectares of glaciers covering about 17% of the mountain areas are undergoing changes due to the warming process. The change in snow content and snow cover on the high Himalayas are, in turn, reducing the water storage as well as water flow

regulatory potentials of these high mountains, causing decreased river flow in snow fed rivers during dry seasons when the water demand for crops and people is rather high. The glaciers during their retreat cause formations of glacial lakes bounded by unconsolidated moraines that, with the rise in water level, suddenly give way causing what is known as Glacial Lake Outburst Floods (GLOFs). These GLOFS are causing growing hazards and hence are drawing growing concerns[4].

Significance

Restoration of Degraded Lands: Community managed forestry has been found quite successful in certain parts of Nepal in protecting forests in the mountains. The community has access to fuel wood and timber products from the forest they manage for meeting their daily needs. Likewise, agro-forestry, leasehold forestry and access to non-timber forest products from the community managed forest are other different modes that have been successfully attempted towards the protection of forest as well as the restoration of degraded lands in the mountains.

People's participation in aforestation as well as conservation of forests is very important in ecological restoration in the fragile mountain systems.

Links to Other Programmes

The project is working in close collaboration with the Mountain Research Initiative (MRI) of IGBP.

Links to APN Goals

The project is consistent with all of the six goals of APN. As the project is in progress, outputs are still coming in. Proceedings of the Scoping Workshop held in Kathmandu in October 2001 have already been published.

Recommendations for future research

Based upon various exercises and recommendations from the aforementioned APN Scoping Workshop, a two-year project proposal with Nepal, India and Pakistan as the participating countries was formulated and is now being funded by APN with goals to:

- Assess the relative importance of global change impacts on the Himalayan mountain environments in order to prioritize monitoring efforts and to anticipate consequences with respect to food security and water resources including transfer of resources between uplands and lowlands;

- Assess the vulnerability of mountain people to global change and to investigate those factors that promote resilience of these groups in the face of multiple and interacting environmental stresses; and

[4] APN is currently funding a GLOFs project (APN 2003-05) which is collaborating with this APN-funded project on Global Change Impact Assessment for the Himalayan Mountain Region.

- Synthesize and aggregate national assessments and other pertinent studies to inform, on a scientific basis, the policy-making processes at local to regional scales regarding global change impact on food security and water resources in the Himalayan Mountains as well as response strategies for coping with and adapting to the changes.

Land Use and Management Change and Trace Gas Emissions in East Asia

Participants

Germany, Indonesia, Japan, Philippines, P. R. China, Thailand and USA.

Rationale

One of the important impacts of land-use and land-management change is on trace gas emissions from terrestrial ecosystems into the atmosphere. For example, land-use change is identified as one of the main sources of continuously increasing atmospheric CO_2; change of aerated ecosystems into flooding use such as flooded rice production alters the ecosystem from an atmospheric CH_4 sink into a CH_4 source; and nitrogen fertilizer application is considered one of the main causes of the steady increase in total atmospheric N_2O sources. However, the impact of land-use and management change on trace gas emissions from terrestrial ecosystems has rarely been quantified. One approach for the quantification of the impact is model simulation. Several models have been developed for simulating trace gas emissions from terrestrial ecosystems, but these models needed to be validated by field measurement data the use of land use and management variables as input parameters to simulate trace gas emissions. On the other hand, land use and land management data sets exist for Temperate East Asia and for Southeast Asia, but are not currently linked or used by modellers. To validate existing models and to link models with land use and management databases, we proposed a study on "land use and management change and trace gas emissions in East Asia." This project, which was funded by APN, had the following objectives:

- Develop an East Asian trace gas flux database;
- Continue developing the Temperate East Asia and Southeast Asia land cover database;
- Integrate agricultural land management into a land use database;
- Link this database;
- Evaluate methodologies, using the database, to project regional trace gas emissions; and
- Consider mitigation strategies.

Major Findings

The DNDC model was validated by field measurements of CH_4, N_2O and NO fluxes from agricultural soils in Japan P. R. China and Thailand. The results showed that the model could simulate seasonal N_2O emissions from lowland soil in Japan, and CH_4 emissions from most rice field sites in China. However,

simulations of NO emissions from agricultural soils, N_2O from an Andisol in Japan, and CH_4 emissions from most rice fields in Thailand were poor. If the model could adequately simulate trace gas emissions from one year or one treatment at a site, it could also adequately simulate emissions from other treatments in the same site and in different years. Modification, however, might be needed before the model can be applied. The sensitivity test of the DNDC model showed that management of rice-based agricultural systems significantly affect CO_2, CH_4 and N_2O emissions with a global warming potential (GWP). We discovered that current land use databases do not adequately support trace gas modelling efforts because these databases rarely contain information on variables such as soil properties, crop rotation, fertilization, irrigation, crop residues management, and so on.

Significance

As the current land use and management databases could not provide sufficient information for model simulation of trace gas emission at a regional scale, we failed to estimate these gas emissions from terrestrial ecosystems in East Asia. The failure of the integration of the existing land use databases and model simulations suggest that communications between developers of land use databases and modellers is urgently needed to match the information available in the databases with the needs of model simulation.

We established a trace gas emission database, which includes more than 80 data sets from 36 locations in India, Indonesia, Japan, Philippines, P. R. China and Thailand. About 60% of the sets contain only CH_4 flux data and the remainder contains both N_2O and CH_4 data. The majority of the data sets are from rice-based agricultural systems. We developed a land use and management spatial database of East and Southeast Asia at a 1 km resolution. Two manuscripts have been prepared for publication in Global Biogeochemical Cycle. Three workshops were held in P. R. China, Philippines, and Thailand, and two seminars were convened in Philippines and Thailand.

Links to APN Goals

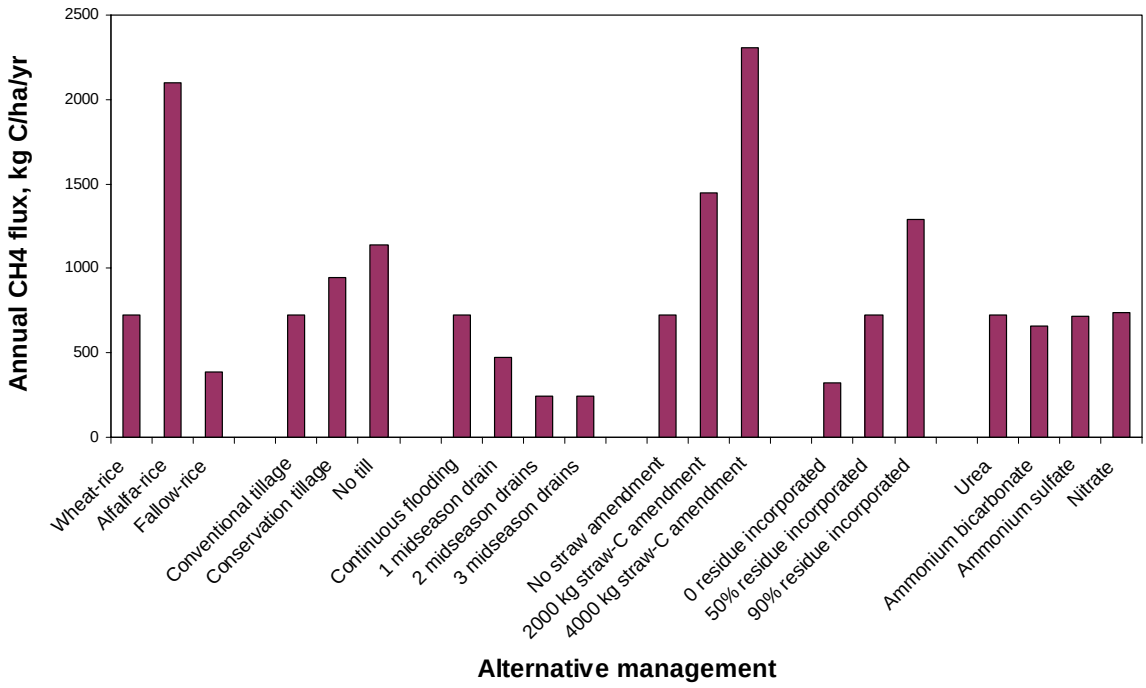
The fifteen project participants were from USA (2), Japan (2), P. R. China (4), Philippines (2) and Thailand (5). Overall, more than 50 people involved in trace gas emissions from terrestrial ecosystems, model simulation, land use data base and remote sensing participated in three workshops and 44 researchers and graduate students were trained using the DNDC model.

Through the project, regional cooperation in global change research was strengthened (APN goal 1), the capabilities of using the model to simulate trace gas emissions were enhanced through training researchers and graduate students (APN goal 3), and a trace gas emission database was established (APN goal 4). START supported the development of a trace gas database and a land use and management database. A poster session was held during the Global Change Open Science Conference in Amsterdam, July 2001, thus providing a platform to highlight this APN project (APN goal 5). Six posters were presented by people involved in the project.

BOX 7: Land Management in East Asia and Carbon Flux Measurements

Changes in farming practices in rice paddies in P. R. China may have led to a decrease in CH_4 emissions and an observed decline in the rate that CH_4 has entered the Earth's atmosphere over the last 20 years. CH_4 is 21 times more potent as a greenhouse gas than CO_2. In addition, since 1750, CH_4 concentrations in the atmosphere have more than doubled, although the rate of increase has slowed during the 1980-90s. Currently, about 8% of global CH_4 emissions come from the world's rice paddies. As an effort to reduce water use, farmers in P. R. China have found that if they drain their soil, they can get higher yields. This is because draining stimulates rice root development, and also accelerates decomposition of organic matter in the soil to produce more inorganic nitrogen, which is an important fertilizer. CH_4 is produced by soil microbes in paddy soils under anaerobic conditions, or in the absence of air or oxygen. Midseason drainage aerates the soil again, and hence interrupts CH_4 production.

From: "SHIFTS IN RICE FARMING PRACTICES IN CHINA REDUCE GREENHOUSE GAS METHANE", 2002.



Recommendations for future research

Many kinds of land use and management databases and models for simulation of trace gas emissions have been developed recently. However, modellers rarely use information provided by land use and management databases. This is because models need input parameters and information available in databases that are currently not well matched. In fact, a more specific land use and management database should be developed for model simulation of trace gas emissions from terrestrial ecosystems. On the other hand, model developers need to think about the data available for their input parameters.

PABITRA Island Ecosystems Analysis

Participants

Participants from the Cook Islands, Fiji, Guam, Niue, Samoa, Solomon Islands, Tonga, Vanuatu and USA were funded to attend the APN/PABITRA Field Biology Training & Joint Analysis Workshop held at The University of the South Pacific November 18 - December 3, 2002:.

Rationale

Land-use and land-cover changes are rapidly taking place and are proportionally large under the global change scenario in island ecosystems. Islands by definition are small isolated landmasses surrounded by ocean. Their biological resource zones (watershed forest, agro-ecosystems, fresh water and coastal saltwater ecosystems) are limited in size and biodiversity. They are spatially close together and functionally interlinked. Together they form the traditional human support system. Therefore, these ecosystems should be managed and researched as holistic landscapes from mountain to sea for sustainability into the future. Moreover, any development should be approached from an islands' cultural perspective. This requires respect for any evolved island culture and research by the natural and social sciences in an integrative manner. The **P**acific-**A**sia **B**iodiversity **T**ransect network, known as PABITRA, was initiated under these premises.

One of the PABITRA network's research avenues is to do comparative ecosystem studies within the same major island biomes (upland/inland forests, agricultural croplands and coastal zones) **horizontally** across the Pacific from the outlier islands of the Paleotropics to Southeast Asia. According to biodiversity theory, the ecosystems belonging to the same biome types are expected to vary functionally from east to west because of their different biodiversities. Another research avenue of PABITRA is to study the three major biological resource zones **vertically** from the Island Mountains to the fringing reefs. The significance of this approach is to involve Pacific islanders in interdisciplinary research and to gain a better understanding of the interaction of the three systems for integrated management.

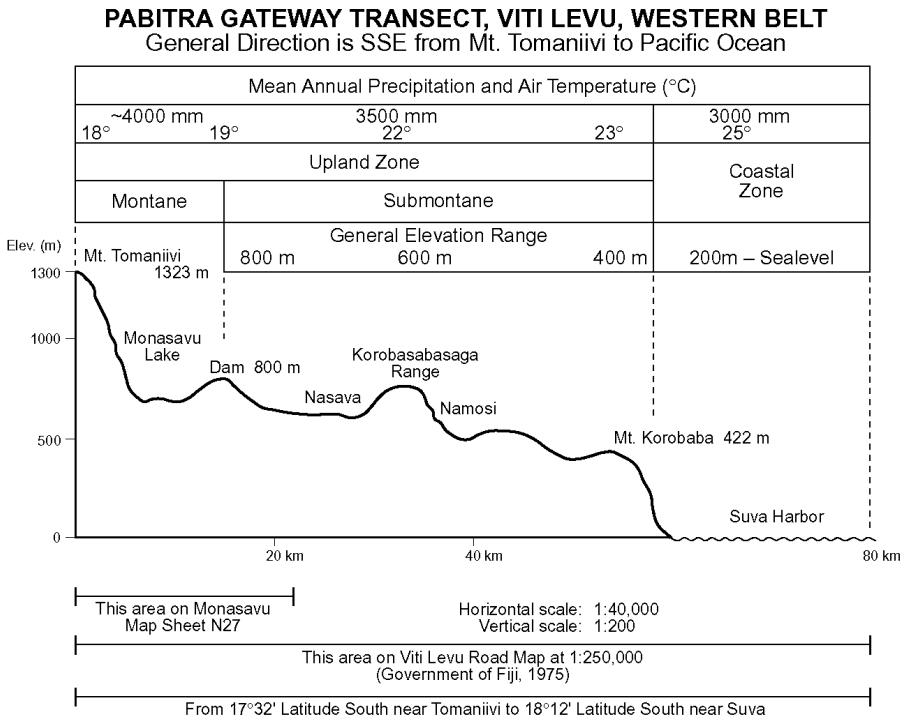
Information will be presented in the form of maps and profile diagrams at scales appropriate for management and policy. Management requires information at detailed levels such as 1:10,000 to 1:50,000, whereas information for decision-makers at the policy level requires information at the overview level of scale, such as 1:100,000 and smaller. Additional information will be presented in the form of posters, illustrated brochures, technical reports, and scientific papers. PABITRA is also the programme of the Ecosystem Division in the Biodiversity Task Force of the Pacific Science Association (PSA), which promotes cooperative research across the Pacific.

The goals coincide closely with those of APN. They relate to (1) regional cooperation, (2) providing scientific information to policy-makers and island

communities, (3) involving Pacific islanders in all work aspects, (4) using standard methodology for biodiversity assessment and evaluation of island ecosystems, (5) being in contact with the global change programme DIVERSITAS and DIWPA (DIVERSITAS in Western Pacific and Asia), and (6) using the economy of scale in terms of the cost and research effort through partnership agreements.

BOX 8: PABITRA and a Transect Profile of Viti Levu, Fiji

PABITRA, the **P**acific -**A**sia **Bi**odiversity **Tra**nsect network, is the tropical island branch of DIWPA, the international network of **DI**VERSITAS in the **W**estern **P**acific and **A**sia. The design of DIWPA includes a north-south oriented "Green Belt" from Russia via tropical East Asia to Australia and New Zealand, and a roughly parallel running "Blue Belt." The research focus along the "Green Belt" is on biodiversity relations in a number of selected forest and lake ecosystems. The research focus along the "Blue Belt" refers to biodiversity studies in selected coastline ecosystems. PABITRA, the East-West ranging "Tropical Island Belt", intersects with several DIWPA sites in the continental islands of the Western Pacific (New Guinea, Borneo, Philippines, and Chinese Taipei). PABITRA's research focus combines the horizontal and vertical approaches to ecosystem studies. This implies an initial concentration on comparative biodiversity research of the indigenous upland and inland forests of the high-island archipelagoes as ecological reserves and watershed covers; the horizontal approach. At the same time, it implies cross-ecosystem studies from the watershed covers down to the fringing reefs; the vertical approach.



(D. Mueller-Dombois, 2002)

A more immediate goal for relating APN sponsorship to PABITRA is planned for the 20th Pacific Science Congress in Bangkok, March 17-21, 2003. Under the Biodiversity theme, PABITRA is organizing a symposium entitled "Island Landscapes under Global Change: the PABITRA Project." Further information

is available at the PABITRA website <http://www.botany.hawaii.edu/pabitra> and also at the PSA Congress website <http://www.20pscbangkok.com>.

Major Findings

PABITRA received funding from APN in April 2002 with the immediate objective to establish the PABITRA Gateway Transect in Fiji. An Initial Synthesis Meeting was held from 15-19 July, 2002 at the University of the South Pacific's Institute of Applied Sciences. Two overseas collaborators (Harley Manner from Guam and Dieter Mueller-Dombois from Hawaii) met with 12 Fijian collaborators. Together we lined out a broad landscape transect from Mount Tomaniivi to Laucala Bay on Viti Levu and determined six biodiversity study sites from the Wabu Watershed to the Rewa River Delta. We discussed the preparation of background data. A second meeting took place from 18 November to 3 December 2002 in two sections. In section I, the PABITRA Fiji Group carried out a Field Biology Training course in accordance with the new PABITRA Manual. Section II, the Joint Analysis Workshop, followed immediately (from 25 November to 3 December 2002). Marika Tuiwawa, the Fiji PABITRA coordinator, invited eight overseas collaborators with different specialties for this workshop. We spent six days of the nine-day workshop in the field with a number of students, the USP faculty, as well as the Government of Fiji and NGO delegates. We visited all pre-selected biodiversity sampling sites, discussed and demonstrated our PABITRA Biodiversity Assessment Methodology, and stayed overnight in Fijian villages. Here, our objectives were clarified in colloquial terms and sanctioned in Sevu-Sevu ceremonies with the village elders.

Significance

During the Joint Analysis Workshop, we established the Fiji PABITRA Landscape Transect. At the conclusion of the workshop, students reported on what inspired them and what they had learned. Twenty-five students received Certificates of Participation. We also discussed plans for the final meeting at the 20th Pacific Science Congress in Bangkok, 17-21 March 2003. The PABITRA Symposium at that Congress is "Island Landscapes under Global Change". Six Fijian PABITRA collaborators are invited with APN funds to present papers on their new Landscape Transect. A similar number of PABITRA Manual Contributors are also invited to present papers, the best of which will be selected for publication in Pacific Science.

Recommendations for future research

At the Pacific Science Congress in Bangkok, a PABITRA workshop will be conducted. Plans for establishing similar landscape transects in other island areas will be discussed and the next target island areas are Samoa and Micronesia. Biodiversity study-sites will be established along each transect from sea to summit and follow-up research cooperation is planned with island resident scientists and students. They will be given the lead authority and help will be offered to them for writing proposals for scholarships.

4 Emerging Themes in Land-use and Land-cover Change Research

The projects listed in the previous section provide a very good base for global change research in Asia and the Pacific. The work funded by APN is now contributing to major initiatives in carbon cycle research, decision support systems for policy and natural resource management, and information supporting sustainable development. This section outlines some of the major emerging themes borne from this suite of funded initiatives. It is believed by the workshop participants that these themes provide focus for future efforts by APN.

The report identifies two overarching thematic areas:

- LUCC information for carbon cycle research; and
- LUCC information for decision-making and sustainable development.

The broad support provided by APN covers many other areas as well, and the identification of these two theme areas is not intended to be exclusive. Rather, they provide a basic framework upon which APN might focus efforts to increase its resource investments above and beyond its current levels, and hence the identification of two key areas provides a more targeted and strategic perspective given limited funds and resources.

LUCC Information for Carbon Cycle Research

Carbon is an essential element for life on this planet; approximately half of the mass of plant and animal life is composed of carbon. Carbon exists in several forms and is cycled between several biotic and abiotic reservoirs, including the oceans, terrestrial plant biota, and the atmosphere. The largest pool of carbon is the lithosphere, but it is relatively inactive. On the other hand, the carbon content of the atmosphere has varied considerably over the past several thousand years, and this variation has been closely coupled to changes in global climate. Variations in atmospheric CO_2 are related to changing fluxes of carbon between the atmosphere and the biota, oceans, and fossil fuels.

Since atmospheric CO_2 measurements were first systematically made in the late 1950s (Keeling 1960, Keeling *et al*., 1976) the concentration has steadily increased (Bacastow and Keeling 1981, Keeling and Whorf 1994). This increase in atmospheric carbon is attributed to two sources: land-cover change and the combustion of fossil fuels (Houghton and Skole 1990, Schimel *et al*. 1995). Fossil fuels have been injected into the atmosphere at a steadily increasing rate since the beginning of the industrial revolution, around 1860 (Marland and Rotty

1984, Keeling 1994, Marland *et al*. 1994). Carbon has been released from deforestation and other land-cover changes over the last 300 years (Houghton and Skole 1990, Houghton 1994).

While the annual increase in carbon content of the atmosphere and the amount of carbon released from fossil fuel combustion are relatively well known, the exact magnitude of fluxes between the atmosphere and the biota and between the atmosphere and oceans are uncertain. These uncertainties confound our ability to construct a balanced global budget for carbon.

With the development of techniques to analyze the concentration of CO_2 in bubbles of air trapped in deep ice cores, it is also possible to estimate the historical atmospheric concentration of CO_2. Since 1750 there has been a steady increase of CO_2 from 280 to 368 ppm in 2000 (IPCC TAR). Human activities are largely responsible for the observed increases and fossil fuel burning is currently the most important source of CO_2. Yet, evidence from ice cores suggests atmospheric concentrations of CO_2 began to rise prior to 1850, even before significant inputs from fossil fuel combustion. Approximately 30% of the current net flux of CO_2 is biogenic and related to anthropogenic land-cover changes. Moreover, the long-term historical release of CO_2 from human alterations of land cover has been approximately equal to the release from fossil fuel burning (Houghton and Skole 1990).

Net additions to the atmosphere from fossil fuel combustion and biomass oxidation are partly removed by oceanic uptake. However, oceanic uptake from the atmosphere is lower than additions to it, and the atmospheric concentration has risen as a result of this imbalance. Measurements of the atmospheric increase when compared to estimates of the net flux of biogenic carbon, fossil fuel emissions, and ocean uptake cannot be accommodated in a balanced carbon budget.

The IPCC Second Assessment Report (SAR) (Houghton et al., 1995) suggested several possible mechanisms to explain an unbalanced carbon budget including increased forest carbon storage due to climate-induced changes in ecosystem metabolism, fertilization by CO_2 or nitrogen, or unaccounted land-use changes such as forest re-growth.

Recent analyses have suggested a large, unaccounted net sink in undisturbed, predominantly northern, forest ecosystems. These analyses utilize a constrained approach, coupling measurements of the north-south gradient of atmospheric CO_2 concentrations and measurements of oceanic uptake and pCO_2, estimates of land surface fluxes from fossil fuels and deforestation, and a general circulation model. The approach provides a geographically-specific assessment of sources and sinks which is highly dependent on the magnitude of the uncertain biogenic tropical source term. Thus, a combination of constrained analyses of this kind and ecosystem models would be required to further elucidate the nature of the sink.

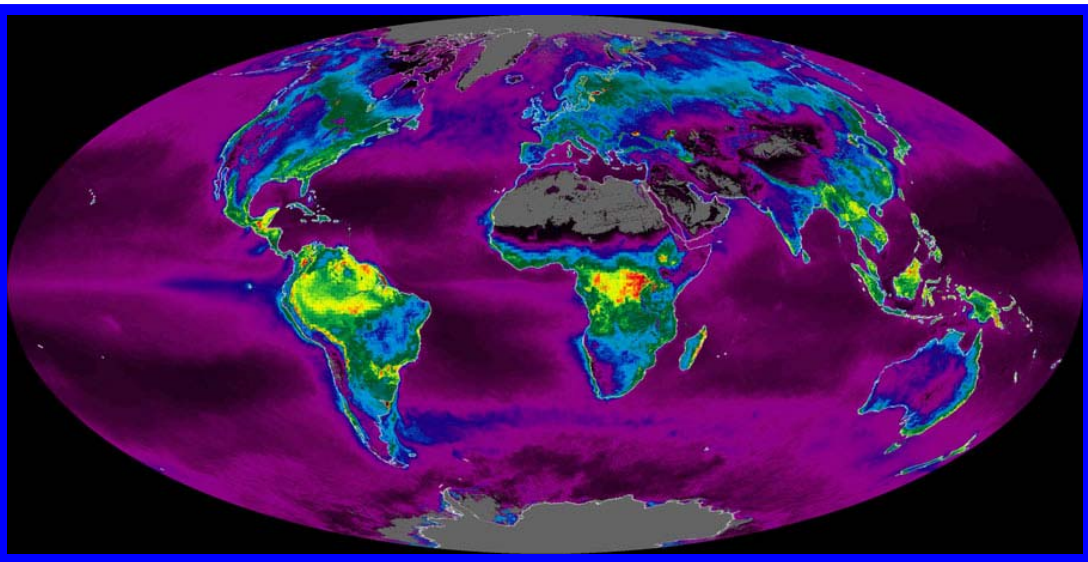


FIGURE 4-1: MODIS Composite of Global Net Primary Production (NPP): A Measurement of Earth's Carbon Metabolism

An important consideration in such analyses is knowing the biogenic flux from land-cover change, particularly the tropical deforestation component. Improved definition of the imbalance in the global carbon budget will come with better definition of the individual terms of the equation above, with the biogenic term being particularly important. Moreover, the use of constrained analyses, in which additional terms to the equation are inferred as residuals from known terms, will require increased geographical and temporal specificity and confidence in the estimate of biogenic fluxes.

Of the combined global net flux of carbon from fossil fuel combustion and land-use change in 2000, approximately 30% is from temperate and tropical Asia. The global net flux from fossil fuels is ~6.1 x 10^{15} gC yr^{-1}, while the global net flux from land cover conversion is ~1.7 x 10^{15} gC yr^{-1}. The net flux from fossil fuel combustion in Asia is ~1.5 x 10^{15} gC yr^{-1}, and the net flux from biogenic sources is 0.8 x 10^{15} gC yr^{-1}. The fossil fuel emissions from Asia represent 25% of the global total fossil fuel inputs to the atmosphere, while the biogenic emissions from Asia represent almost half of the global total inputs from land-cover change. The contribution of China's fossil fuel emissions is approximately 43% of the regional total fossil fuel emissions, 10% of the regional biogenic flux, and 32% of the combined fossil fuel and biogenic emissions. When we exclude the Pacific Developed countries, which include Japan, Australia and New Zealand the fossil fuel emissions from Asia are only 18% of the global total fossil fuel inputs of which China's contribution is almost 60%. Currently this is an important region in terms of its biogenic contribution to the global totals, probably more so than in terms of its contribution from fossil fuels. The Southeast Asia sub-region is significant in its contribution of biogenic emissions, contributing almost half of the global total.

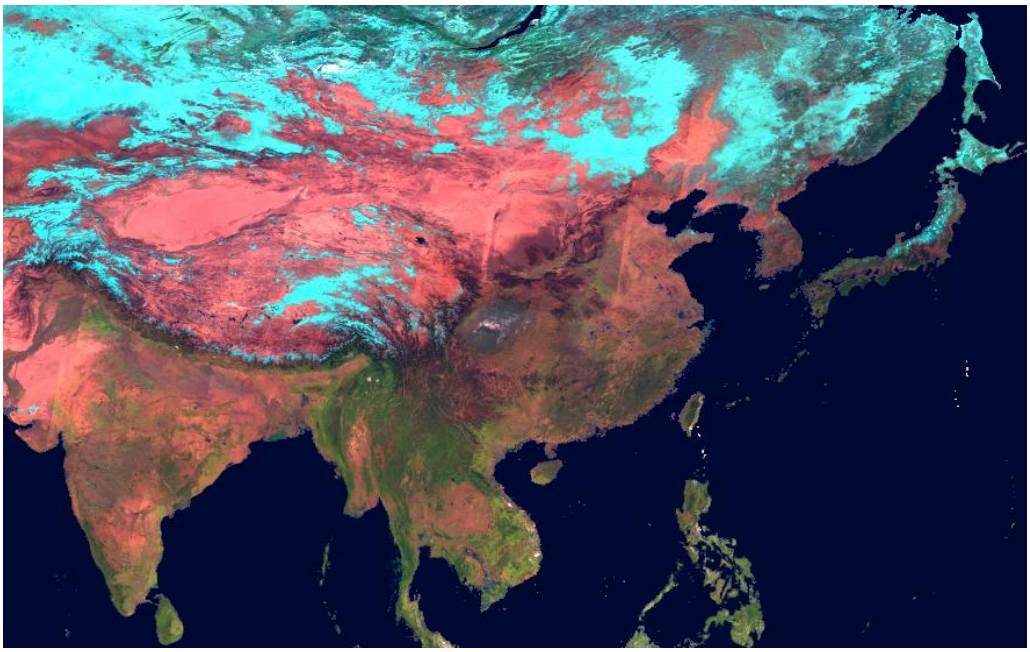


FIGURE 4-2: SPOT VGT 10-Day Composite NDVI

However, it should be noted that growth rates of fossil fuel emissions since 1970 have been significant in this area of the world, and future emissions of fossil fuel carbon will likely be very high in rapidly developing China and the so-called "Asian Tiger" countries of Southeast Asia. The growth rates in fossil fuel emissions in the last 20 years for China and Southeast Asia have exceeded the overall global rate of increase several fold (213% and 240% respectively, versus 49%).

LUCC Information for Decision-making and Sustainable Development

At the beginning of the 21st century, the world is facing significant new scientific, technical, and economic challenges for natural resource management including the prospect of rapid environmental and climate change, the threat of hunger and disease, and the relationship between environment and development. Disproportionate vulnerability to external events and situations results in poverty and social dislocation. Weakened local and national institutions cannot respond to public needs or give voice to the needs of the people. Much of the information needed to address complex questions of sustainable development is spatial in nature, in that the relative location of people, animals, resources and threats matter; relationships among places such as villages, cities and regions matter; and change must be monitored over both time and space. Integrated geographic information contained in a geographic information system (GIS) can foster public participation in decision-making by providing a window on social,

economic and environmental conditions at local to global scales; improve economic development by providing governments with information about informal and new markets; foster land, labour, and government productivity and efficiency; and help countries meet their international goals and obligations.

The application of geospatial information and technologies and of integrated geographic perspectives on environment and development can help implement a new approach, sometimes referred to as Geographic Information for Sustainable Development, or GISD. Geographic information lies at the heart of most issues of sustainable development. Many decisions related to natural resource management and development planning are sounder when informed with geographic information. The last decade has brought a revolution in many aspects of geographic information, with a concomitant increase in the potential for addressing the sustainable development issues described above. Satellites now offer broad, high-resolution (even real-time) coverage of a range of features on or above the Earth's surface; hand-held receivers of data from the global position system (GPS) have evolved into practical tools for pinpointing the location of features on the Earth's surface; other tools for managing geographic data and information, such as geographic information systems (GISs), have become both increasingly sophisticated and easier to use. A parallel increase in the ability of computers to handle large amounts of geographic data; training in and understanding of geographic information sciences (GI Sciences) has increased capacity for developing decision-support systems and feeding them with geographic information; and lastly, telecommunications networks and technology have grown and become increasingly efficient at transmitting geographic data and information, and disseminating geographic knowledge.

But despite this progress overall, advancements have not been uniform across the globe; the "digital divide" has expanded between those that benefit from these and other technological advancements and those that do not. There remains a great challenge in making geographic information accessible to those that need it across all sectors and scales, and in both urban and rural areas.

This project will advance the widespread use of geospatial technologies to the widest possible number and type of users, from national planning and resource management agencies, to local communities and individual farmers. We outline an approach that specifically targets the multi-scale and multi-use aspects of remote sensing and geographic information systems. To do this we will undertake, test, and transfer a set of research and development activities in three broad areas:

1) *Development of New Resource Measurement and Assessment Tools*, which will involve the development of local, national and regional methods for natural resource inventory and classification using remote sensing and GIS.

2) *Development of Spatial Decision Support Systems and Spatial Data Infrastructure* for local, national and regional assessments and planning with specific approaches tailored to the scale and user. This will include

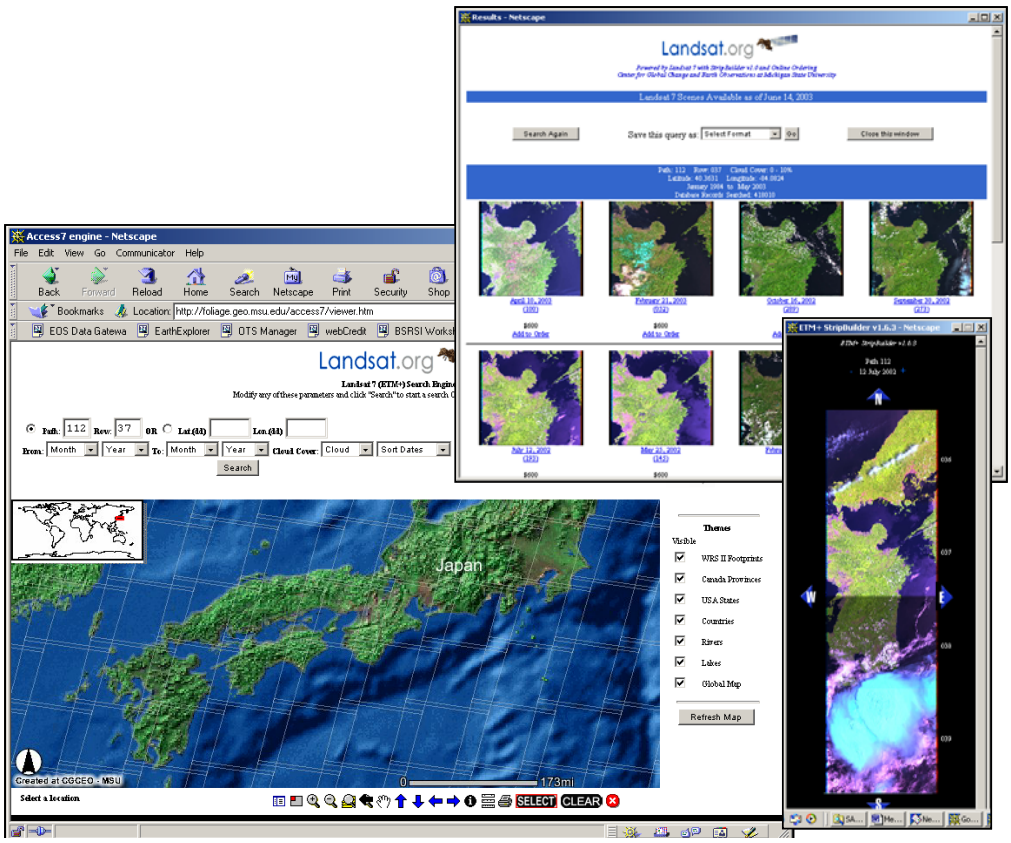


FIGURE 4-3: Internet-GIS: Search, Browse and Order Application for Global Landsat Data

community mapping with photo prints for local and low technology users, as well as internet-based geographic information systems.

3) *Outreach, Technology Transfer and Use* by different sets of users with different scales of use. We will test the multi-scale applicability of geospatial technologies in sites where there are three levels of stakeholders simultaneously active in the management of resources – local villagers, local government authorities, and national resource management agencies (cf. the TamDao National Park in Viet Nam and Magat Watershed in the Philippines, where all three levels of land managers interact). We will also deploy technologies individually for local problem solving, national resource inventory needs, and ASEAN-wide, cross-national harmonization demands.

Interactions: social, environmental, sectoral and spatial

The combined and exacerbating effects of land use and climate change (particularly extreme climate events which are enhanced through intensive land-use changes) make environment and development problems in Southeast Asia particularly difficult. A complex problem-set of multiple stresses force planners to make trade-offs between conservation and exploitation. This is particularly important at the interface of natural resource management and agriculture. In an era of rapid environmental change,

decision-making will need a rapid infusion of low cost but timely information and information technologies. Geospatial information and technology hold great promise for management and mitigation efforts, and a clear demonstration of how these tools can support these efforts is required.

Moreover, new research and information is required at the intersections between resource systems and sectors, for example climate, forestry and agriculture. There is recognition by planners, decision-makers, and government officials in the region and globally, that this century will be marked by new problems at the intersection of agro-ecosystem change, climate change and land-use change. Recent research carried out in Southeast Asia highlights the impact that land-cover change in the upper reaches of watersheds has on flooding and agriculture in the lower reaches. Extreme climate events are exacerbated by land-use change and mismanagement of natural resources and may result in natural disasters that can set back nations trying to invest in sustainable economic and natural resource development and conservation (ADPC 2000, APDMC 2000, Indochina Global Change Network 2000, Natural Disaster Mitigation – Partnership, 2001). The United Nations International Strategy for Disaster Reduction notes that the effects of climate change and the risk posed by the increasing degradation of the environment, epitomized by deforestation contribute to an increase in human vulnerability, through loss of life, material loss, loss of food production capacity, and overall environmental deterioration (UNISDR 2002). Nowhere else are these problems more acute than in Asia where nearly 43% of all natural disasters in the last decade have occurred (UNISDR 2002).

Advances in Use of Geospatial Technology and Information

1) Technology and Data are Freely Available. There have been many changes in the field of geographic information science, which now make widespread use of geospatial technologies possible. First, the cost for most geographic and remote sensing systems has come down considerably, making it possible to have all the necessary data processing and information management software running on low cost desktop PCs. There are now many widely available PC based systems that are low cost or free. For example, the IDRISI system is available for less than $100. At the same time, massive amounts of data are becoming available at very low cost. These include census and other statistical or map databases from national agencies and satellite imagery, including the Landsat series data which once cost as much as several thousand dollars per scene are now available for less than $500, or free in most cases since there are no longer any copyright license requirements. Other public domain sensors, including the NASA Terra series are all available at the cost of fulfilling the user request.

Hence, several types of earth observation data that were unavailable a decade ago are now available and of significant relevance to sustainable development concerns. For example, the Landsat series of high resolution imaging sensors can provide routine coverage of the whole of Southeast Asia on a regular basis. This data may be obtained from the local ground stations in the region or from the US national archives through a system called Access-7 via the website at

<http://www.landsat.org>. The user community in the region can have complete coverage at no charge. This will be the first time prohibitively expensive data will be provided to governments and citizens alike free of charge. Land-use change, agriculture mapping, and forest inventory application can and will be applied.

2) *Expansion of the Internet has greatly enhanced global communications over the last decade.* More recently, the emphasis on geospatial information has turned toward spatially open and distributed web-based data services, as high-speed, high-volume lines become available. Four interrelated categories of usage have emerged: (1) advertising: concerned mainly with on-line research projects, new methods and tutorials, and data products; (2) data access and distribution: allowing users to search for specific information and data objects and download data sets; (3) custom map creation: providing maps using tools that can compose, download, and display user-defined map products through a web browser; and (4) complete GIS/Internet integration: integrating a limited amount of front-end query capability with database management systems and GIS software packages residing in the background.

Today, as many development assistance agencies embrace geospatial information, many types of partnerships have emerged for sharing geographic information. The largest and most ambitious partnership, the Global Spatial Data Infrastructure (GSDI), strives to bring all countries together to collect, maintain, and disseminate data according to established and internationally-agreed upon standards and formats. Other international organizations such as UNEP have entered into partnerships with national and regional organizations, such as EIS-Africa, to create useful data sets. UNEP and FAO have recently formed the Global Land Cover Network, with the aim of enhancing the use of geospatial information for sustainable development, and are forming partnerships at the national and regional level. Of particular interest is the new AsiaCover programme which will develop land cover classification for the Southeast Asian region, and will support both national and community-based applications. Overseas development aid organizations such as ITC and USAID partner with national organizations to promote the use of geographic information.

These new developments have also supported the on-going work of SEARRIN. The salient issue here is that through the use of remote sensing and GIS, the SEARRIN group has been able to make significant advances in distributed regional collaboration as the partnering and human resource infrastructure for bringing new geospatial technologies directly to use in the region.

New Methods for Natural Resource Inventory and Measurement of Change

Most importantly, new methods are being developed which make it possible to do much more with remote sensing technologies than in the past. Land-use and land-cover change classification is becoming routine, and the United Nations Food and Agriculture Organization has now published and disseminated a

standard Land Cover Classification System which is being widely adopted for use with remote sensing observations. Landsat 7 data is now routinely collected globally, with an acquisition schedule for obtaining four complete cloud cover free national coverage for all Southeast Asia annually. NASA is making these data available at no cost to the United Nations and the public at large for the year 2000, with follow-on opportunities being planned. The Southeast Asia region is being routinely covered by Landsat as part of the United Nations GOFC/GOLD Programme, and in support of the new UNEP-FAO Global Land Cover Network (Principal Investigators in this project are leading these UN programmes, see <http://www.gofc.org>).

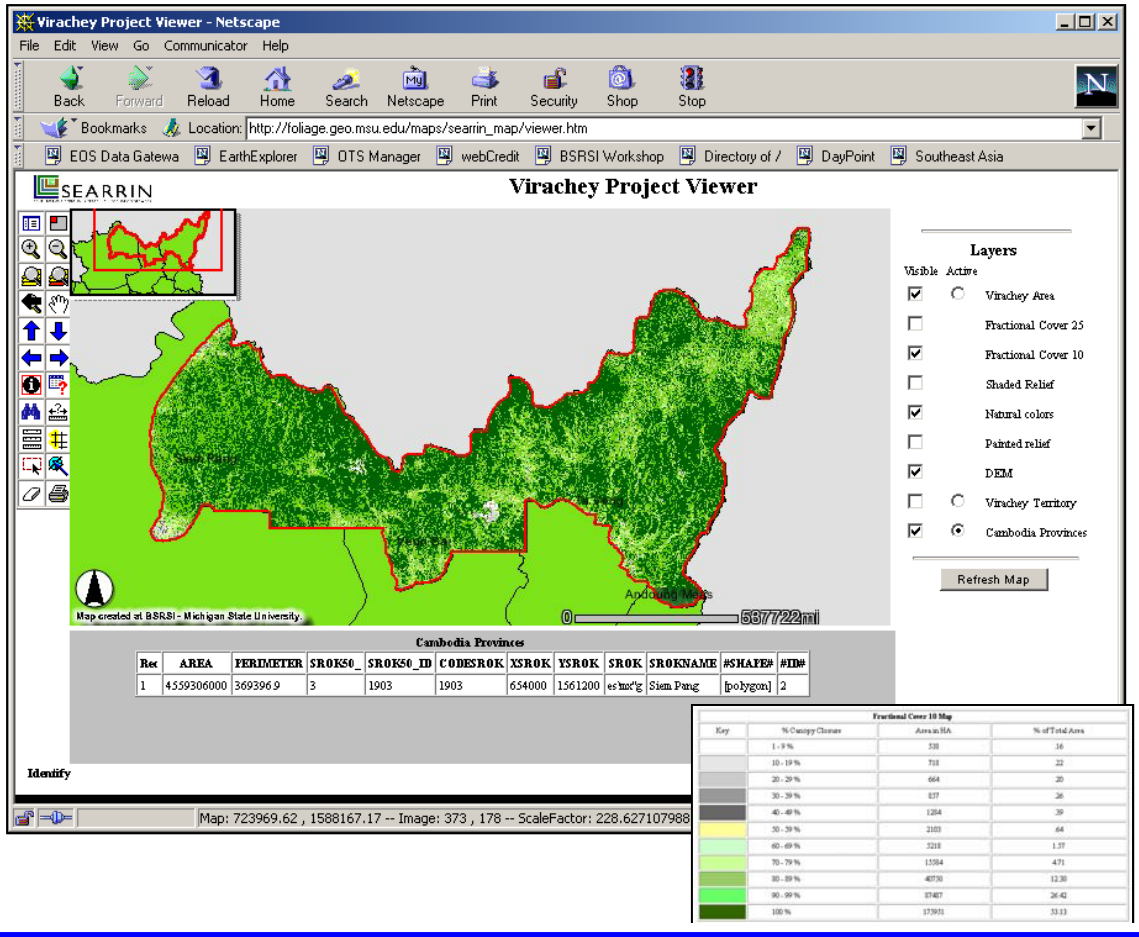


FIGURE 4-4: Internet-GIS for Natural Resource Management of Virachay National Park, Cambodia

In addition to classification, new methods of fractional cover are providing techniques for developing percentage tree cover maps and continuous fields of forest density at scales ranging from 30-1000 metres. New techniques, such as the K Nearest Neighbour (kNN)) technique are being developed which link point measurements, such as forest stand inventories with remote sensing data for spatial extrapolation. These types of mapping techniques allow measures of changes within classes and can account for natural resource degradation, where

classification usually only captures outright transformation or loss. These methods are also more closely tied to the kinds of natural resource inventory and status techniques typically performed by ground based sampling; it is now possible to develop measures of natural resource conditions to supplement ground based programmes, and thus greatly enhance already limited human resources.

Geographic Information for Sustainable Development (GISD)

These ongoing developments in the analysis of satellite imagery and the applications of geographic information systems (GIS) have opened new frontiers for the synthesis of multiple, complex and diverse data sets. Managing and mitigating the effects humans have on the environment across a range of scales from local to regional and the dynamic spatial interactions between the social and biophysical systems can be enabled through the development of a geographical and spatial approach to these problems. A geospatial approach provides both an analytical framework for research, and a tool for practical application to planning and decision support. Advances in technologies such as earth observation satellites and equipment to capture geospatial information are continuously improving information quantity and quality. More spatially explicit information is creating new opportunities for collaboration between social and natural scientists and approaches to developing decision support systems that integrate these increasingly complex and diverse data sets.

The issues that GISD has identified for Africa are the same as those that confront Asia and the Pacific. While the observations, data, and technologies exist – and can be distributed using the World Wide Web – ***access remains a critical problem***. One of the key obstacles to access and eventual utilization by planners and decision-makers is the lack of clear models and examples which demonstrate how the large global observing systems can be tapped for local (i.e. watershed) and regional (i.e. trans-boundary) problem solving by ordinary decision-makers. To quote a recent report on GISD: "An abundance of earth observation data is of little value if it cannot be provided to those who need it most." Moreover, it is not enough simply to provide this data to policy-makers and natural resource managers. The aim here is to develop a suite of outreach mechanisms to provide timely, accurate, geospatial information in formats understandable to decision-makers and natural resource managers for improved sustainable development practices and policies.

5 Data and Infrastructure

All of the funded projects have been producing important datasets. More recently, APN has been encouraging projects to explicitly develop information outreach and dissemination efforts within their projects, and some efforts have been expressly focused on information systems development. With the emergence of low cost, web-based geographic information systems, increasingly available remote sensing data, and massive amounts of *in situ* observations, the development of information systems for widespread access to timely data has been an important aspect of conveying science results into policy.

Overview

APN has been very successful in developing information systems, which make both data and decision-relevant information available to a widening user community. This democratization of information has made it possible to distribute information and products from funded research in ways not possible even a few years ago. Through APN support, the region is now seeing the emergence of information centres, or nodes, within the networks of active scientists and participating institutions. Web-based GIS nodes are being implemented for data sharing and information access in Indonesia, Malaysia Philippines and Thailand. These data nodes are complemented by active ground receiving stations, as in the case of the Thai ground station for satellite data, which provide routine acquisition of primary observations that can be sent to participating scientists. Once in the hands of APN-funded scientists, the data is used in the projects to produce products for application to a range of policy and management applications. The products are then made available very quickly to other scientists, decision-makers, and civil society in an open and distributed fashion.

These advances are pushing the frontiers of low-cost open distributed information systems and services in ways that are not even seen in some other, more likely, areas of the world. Open access to NASA and ESA datasets is now often more widely available in the Southeast Asia region than in the USA and Europe. However, significant obstacles remain. For example, information infrastructure in some countries such as Viet Nam and Cambodia hinder widespread access to information. In other places, such as Lao P.D.R and the Philippines, access to desktop computers at the decision-makers' home institutions is a hindrance to the use of the data products. A concerted effort to increase overall infrastructure capacity will be an important component of future funding priorities for APN.

Conclusions

Decision-makers in Asia-Pacific countries need data and tools to monitor and assess natural resource inventories and environmental and social change. These data and tools are also needed to predict scenarios (e.g. trends and needs for land and food), determine critical information needs, evaluate data quality, and identify data gaps. Entities ranging from governments to NGOs to farmers can use information from decision-support systems to reduce the impact of global change on human well-being and the environment. Needs and priorities vary among these entities. Therefore, decisions about sustainable development often involve compromises and trade-offs (e.g., setting aside land for wildlife protection versus land for farming, or deciding how much water from a river should be diverted to farming as opposed to industry or housing), and competing demands complicate the decision-making process.

GIS aids the decision-making process by integrating and displaying data in an understandable form. Furthermore, GIS is used to analyze relationships among different kinds of data (e.g., environmental and health data). The fundamental analytical functions of a GIS-based spatial decision-support system include (1) query analysis, (2) proximity or buffer analysis, (3) overlay analysis, (4) neighbourhood analysis, (5) network analysis, and (6) modelling. Various combinations of these functions are commonly used during the geographic data analysis process.

The data and technology needs of decision-makers vary with the types of users. Policy-makers at the national or local level need different information than do the residents of a town or village affected by the decision. Although good decision-making involves all the people who are likely to be affected by a decision, individuals and organizations play different roles in the decision process. Technology must be useful and appropriate to its users. In some cases, advanced GIS and modelling is suitable. In other cases, the use of printed satellite imagery with simple GPS devices is better. Projects operate at both ends of this technology continuum in the Asia-Pacific region.

The first requirement for implementing a spatial decision-support system is access to data. Ideally, decision-support systems use distributed geographic information systems permitting users to obtain data relevant to their needs such as framework data and other thematic data. A geo-library is an example of an open, distributed system that combines the idea of a traditional library with the resources of the Internet. Geo-libraries make geographic data available to those with access to a computer and the Internet.

Distributed geo-libraries are global in reach and are part of the concept of the national and global spatial data infrastructures. Data sharing, necessary for a distributed system, often is inhibited by the lack of precedent and protocols for data sharing among government agencies.

The contribution of decision-support systems to policy dialogue depends on geospatial capacity (e.g., good data and equipment, and trained staff), and communication among policy-makers, scientists, GIS experts and civil society. These interactions are most effective within a fully supportive geo-information policy environment at the national level. In addition, demand will spur the development and use of decision-support systems. The agricultural and natural resource management sectors are a likely primary source of this demand, as these sectors are the main users of geographic data and tools. The livelihoods of the majority of Asians, for example, depend on agriculture and natural resources, and pressing problems within these sectors include soil infertility and erosion, pollution from farm chemicals, pressure from grazing, and competition for resources. Addressing these problems demands better data and better ways of analyzing the relationship between human activities and changes on the land surface. Hence, decision support in the area of land cover will be one of the more fruitful application areas of geographic data and tools.

Management of natural resources and development in a sustainable manner is ultimately a process of evaluation and decision-making. Decision-making is a complex process that involves value judgments and analysis of a broad array of information. GIS is a decision-support tool that integrates many kinds of data into a usable format, permits the analysis of data, and produces descriptive and predictive modelling of alternative scenarios.

Many decision-makers in developed and developing countries have no experience of GIS and other spatial decision-support tools, and thus do not appreciate their potential. Presently, there is a considerable commercial market for geographic information, services, and technologies in the Asia-Pacific region but the need exists for spatial decision-support systems and demand is likely to grow. The agricultural and natural resource management sectors are among the main users of geographic information making land cover a priority area for the development of spatial decision-support systems in the Asia-Pacific region. More interactions within APN with the private sector; human, societal, and organizational capacity are needed to integrate geographic information and decision-support tools into the decision-making process.

Lessons learned

1) **Expand awareness of GIS value and use.** Greater awareness is needed among decision-makers in the Asia-Pacific region of the value and usefulness of GIS analyses. This can be brought about through briefings and workshops where policy-makers have an opportunity to gain a better understanding of how GIS tools are developed and used.

2) **Strengthen the policy dialogue process**. The processes for encouraging and enhancing dialogue between policy-makers and GIS practitioners should be

strengthened in all countries studied. The process should be user-driven and should feature input from all levels of users (i.e. mid-level as well as senior government officials), and from civil society and other stakeholders.

3) **Establish national geographic information policies**. All countries in the Asia-Pacific region should establish national geographic information policies that address key issues and problems related to how this information is developed, accessed and used. Some principal issues and problems include: how to enhance access to information and information sharing; setting the rules that determine standards and protocols for data collection, storage, labelling, and integration; data ownership; confidentiality and privacy; and copyright protection.

4) **Strengthen local capacity**. Capacity building is an essential component of developing national GIS strategies in Asia and the Pacific. GIS capacity should receive more attention from the government and education sectors, and capacity should be developed and based in universities and the private sector as well as government agencies.

5) **Expand access to geographic information.** The results of GIS analyses - including databases, maps, and studies - should be made available to the public through the media, through regular government and private marketing and distribution channels, and increasingly through the Internet. Wider access will help strengthen the policy dialogue process by requiring policy-makers to be more transparent in how they make decisions on resource pricing, allocations, concessions, revenues and use.

6) **Continue to study the use of GIS in policy-making**. Each country in the region should conduct a periodic review of the development and use of GIS, taking into account the interests of the public, government, business, NGOs, academia, and other affected parties. In addition, more countries in Asia and the Pacific should develop case studies on the use of GIS in policy-making, thus building a stronger network of GIS users and experts.

BOX 9: GIS and Policy-making: Examples from Africa

African countries are using geo-information in various ways to produce important economic, environmental, and social benefits.

Enhanced capacity for emergency response

- In Burkina Faso, geo-information experts have used climate, agricultural, and population data to create a famine early warning system, which provided timely, accurate projections of crop shortfalls, enabling the government to take corrective action. Estimates based on geo-information analysis proved more reliable than field-based projections.
- In South Africa, geo-information used in a poverty mapping initiative was combined with information on sanitation and safe water supplies to create a strategy for containing a cholera outbreak in KwaZulu Natal province. Data on illiteracy rates, dwelling types, and lack of basic services provided the basis for an effective, targeted health education campaign. The resulting fatality rate for this outbreak, 0.22%, was among the world's lowest ever recorded.

More effective and efficient government operations

- In Côte d'Ivoire, the Abidjan borough of Cocody used geo-information on land, population, and economic activity within its boundaries to design new procedures for tax assessment and collection, which produced sharp rises in tax revenues from businesses. In response, at least five other boroughs have launched similar initiatives.
- In The Gambia, geo-information helped identify potential sites for future waste disposal facilities in the greater metropolitan area of the capital city, Banjul. Land allocation data from more than ten different borough council systems had to be combined, as several parcels thought to be potential sites turned out to be human settlements.
- In Senegal, a database integrating census data and geo-referenced information on villages and settlements will help monitor and evaluate the national poverty alleviation programme, including its impact on the country's poorest citizens, as well as directing future action.
- In Mozambique, geo-information on the distribution of land mines is guiding de-mining efforts and aiding dissemination of information about the location of mines, as well as safe places and passages.

Increased transparency of public decision-making

- In South Africa, geo-referenced data on population, roads, and physical barriers such as rivers and mountain ranges were combined to delineate the boundaries of electoral wards for the 1999 elections. This information permitted the boundaries to be drawn in ways that sought to minimize difficult travel and overcrowding at polling places and the gerrymandering of. This example goes directly to the heart of transparency with respect to implementing democracy through avoidance of gerrymandering.
- In Côte d'Ivoire, geo-information was used to analyze investments in new village health care centres, contributing to a perception that these decisions would be made based on need and merit rather than political influence.
- Also in Côte d'Ivoire, the availability of more precise information on the size, boundaries, and status of forest concessions provided a basis for a more transparent and fairer method of computing taxes and allocating revenues to local jurisdictions.

From: **"*GEO-INFORMATION SUPPORTS DECISION-MAKING IN AFRICA: An EIS-AFRICA Position Paper*"** by Elizabeth Gavin, 2002.

6 Synthesis: What Next?

This section provides recommendations for a comprehensive programme on LUCC research in *Southeast Asia*, based on current and prospective research capacities in the region from prior APN funded research.

Implementing an APN Land-use and Land-cover Change Strategic Science Agenda in Southeast Asia

Not all of the elements described below need to be implemented. Rather, the programme described below provides a cross section of research elements which would constitute a comprehensive programme of research for the next 10 years which would readily mesh with the various international global change programmes, national needs in the region, and ongoing APN funding.

This potential strategy is written around three strategic areas of concentration:

- The first part of the strategy focuses on the substantive, theoretical, and analytical efforts, many of which dovetail with the IGBP/IHDP LUCC Core Project.

- The second part of the strategy describes some crosscutting areas where theory could be put into practice. These include, in a hierarchical fashion:

  - Data activities,
  - LUCC monitoring,
  - Development of LUCC and land quality indicators, and
  - The development of assessments of LUCC status and trends for decision support and policy.

- The third part describes the implementation of key regional activities, where teams of scientists and scholars could be formed to develop comprehensive and intercomparable focused projects and/or case studies.

Theme 1: Case study analysis of land use dynamics

This element will have two long-term goals: (i) to build a firm understanding of the regional dynamics of land-use and land-cover change through the analysis of case studies in comparative perspective, and (ii) to

offer empirical models of land-use change situations and dynamics at the sub-national to national (local to regional) scales.

In pursuit of these goals, it would address the following basic questions:

- What are the main driving forces and constraints that influence human land managers to maintain or change land use over time?
- What is the nature and relevance of variability in human land use systems that affect land cover and use?
- What are the mechanisms and processes by which land managers develop a land use system, defined in terms of an operation sequence?
- What is the relationship between human purpose and action?
- What are the effects on land cover of the application of land use over time and how do these consequences feedback to land uses and their driving forces?
- What is the relationship between the resilience of social and natural systems and the shape and human potentialities of land use systems?

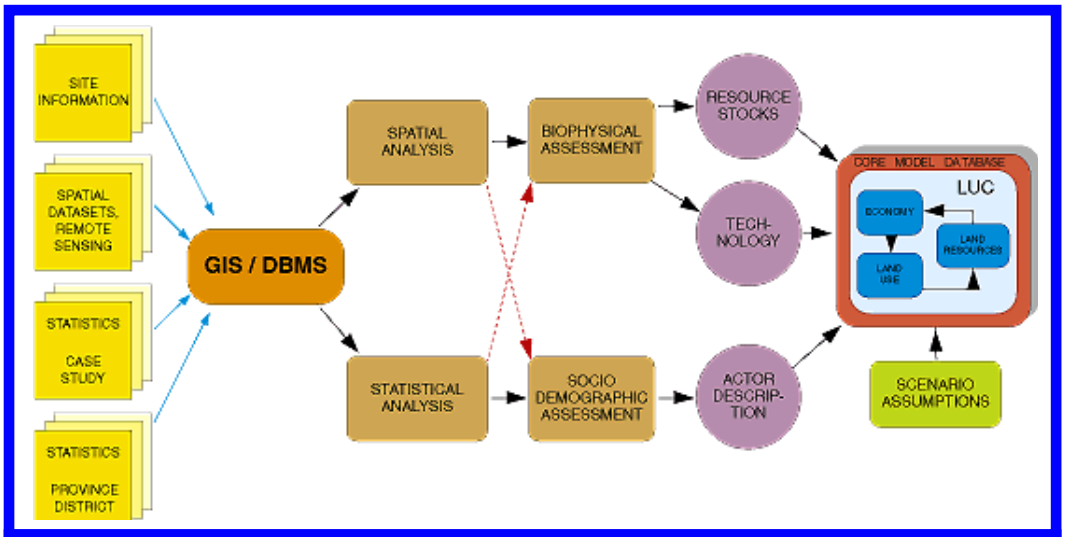


FIGURE 6-1: IASSA/LUCC Modelling Framework

The activities are designed to lead to an empirically-derived modelling framework that builds on case analysis, which is the consideration of micro-scale phenomena (where land management takes place) against other similar phenomena at similar scales, within the ambit of the social system as a whole (Ragin, 1981). The modelling framework will interact with empirical thematic assessments and with integrated modelling efforts. As a modelling effort, activities will also include an effort to determine the scales at which

important social forces, i.e. politics and policy, cultural practices, different forms of social organization on the land, and so on, are most important to land-use and land-cover change, and where they are not important at all, or perhaps important only as rate modifiers.

Theme 2: Development of spatial land use models at case study sites

The importance of this theme comes from the understanding that presently our knowledge of the land-cover change dynamics in Southeast Asia is inadequate due to essentially two reasons: (i) lack of accurate measurements of its rate, geographic extent, and spatial pattern; and (ii) poor capability to model change from empirical observations, from remote sensing and statistical regression analysis.

By advancing our knowledge of the rate and spatial pattern of land-use and land-cover change, and the factors that are driving this change, both global change questions and regional development questions can be addressed. For both of these purposes, it is important to improve our quantitative analyses of rates and spatial patterns of land-cover change, and our predictive understanding of the land use practices that drive these changes. Taking these into account, this theme would address the following questions:

- What are the rates of land-cover change and how will they progress?
- Where is land-cover change presently occurring and where will it occur in the future?
- Which natural and cultural landscape attributes contribute the most to the explanation of land-cover change?

The first step to address these questions consists in the identification of land cover dynamics at broad scales, focusing, whenever necessary, on areas which present a high rate of land-cover change, or a high sensitivity to change. This relates to the concept of critical zones or land-cover change *hot spots*. Once identified, it is necessary to assess the current state of land cover on these critical areas and to determine the rate of change in their land cover attributes. These activities can be achieved using remotely sensed data, due to their ability to provide spatially explicit and repeated measurements at different spatial scales.

The observed changes in land cover can then be spatially and temporally associated with potential proximate causes that can be mapped and integrated into a Geographic Information System (GIS). These associations can be estimated statistically through classic multivariate model designs. The results from such observations and models may provide insights into the driving variables, by highlighting important spatial and temporal occurrences. Once robust representations of the causality process is achieved, it can serve as a basis for generating projections of likely, or future, rates of change. These land-cover change risk maps can then be overlaid on maps of environmental attributes such

as biodiversity, sensitivity to erosion, forest cover etc., to predict possible impacts of projected rates of change.

Theme 3: LUCC developing process model for the entire region

This theme would create a new modelling framework integrating case studies and regional analyses. Developing the basis for a new generation of models is a major task in terms of both database preparation and methodological innovation and will require sustained work. There are, however, near-term needs for more precise land-use and land-cover change projections arising from the IPCC and UNFCCC, and other international bodies. This theme, therefore, follows a two-track approach: a short-term or "fast" track and a longer "development" track. The fast track approach would review existing regional to global scale agricultural, grassland and forestry models to give more reliable land-use and land-cover change projections over the short term (2-3 years). The development track would be aimed at creating a new model structure over a longer term that is capable of a more complete representation of land-use and land-cover change and its main driving forces.

Theme 4: Development of data sets and information systems to support policy- and decision-making

As LUCC research efforts have begun and are becoming a reality, there raises the preliminary need of defining the basic data required for understanding the land transformation processes. Consequently, strategies to achieve, improve, or create these datasets must be designed right now, even though it is assumed the first issue is to match the LUCC research requirements with real possibilities in the light of existing initiatives and frameworks.

Ad hoc information for monitoring and modelling LUCC processes and trends, combining socio-economic and biophysical data, has not been well developed until now; however, some current initiatives can be considered specifically suitable. There exist critical gaps like the lack of databases on socio-economic driving forces linked to geo-referenced land-use and land-cover changes; the lack of geo-referenced data providing accurate information on the rates of land-use change, or the lack of data which describe and characterize global-scale processes in the land surface (e.g., land degradation and changes in soil properties) and their interactions with global biogeochemical cycles and climate.

Mainly, the requirements for any dataset capable of being used in LUCC science activities are derived from the need for achieving a quantification of the studied processes. In this sense, only geographically explicit and geometrically corrected data (both social and ecological) will permit to formalize the research results. Datasets should be integrated with GIS and, therefore, some kind of standardization and geo-referencing is necessary.

Moreover, expert systems and artificial intelligence techniques specific for land use and land cover detection can not only help improve the suitability of land surface classifications, they can also save time and costs, and contribute to the development of continuous monitoring systems.

It would also be beneficial to define the frequency needed for different datasets, and match it with current state-of-the-art, and future, possibilities. Another interesting approach would be to build up ad hoc temporal baselines at regional levels, with respect to the function of the temporal and spatial scales and resolution requirements.

Theme 5: Routine measurement of land-cover change in Southeast Asia

This section defines the initial scope of a LUCC monitoring system, which recognizes the need for a regular LUCC inventory and continuous monitoring in a range of cover types to meet the requirements for multiple users and products beyond the basic research requirements of LUCC alone, such as resource assessments, impact analyses, and policy and planning. The LUCC community recognizes that remote sensing tools provide an objective, continuous and consistent source of spatial data as continuous fields over a range of spatial and temporal resolutions. However, at the same time, it is important to develop systems that include survey, census, and socio-economic datasets. The remote sensing technologies and programmes are far more advanced than anything analogous in terms of socio-economic data, so new efforts need to be placed on the development and implementation of this component of LUCC monitoring.

A hierarchical approach to monitoring needs to be developed taking advantage of the capabilities of a range of sensors and databases. This activity develops the framework for a hierarchical system, which includes both remote sensing and non-remote sensing data.

Theme 6: Research on developing LUCC indicators for trend assessment

An indicator of environmental conditions can be defined as a phenomenon or statistic associated with a particular environmental condition. Indicators of land quality change may include direct and indirect indicators. A direct indicator will generally form a diagnostic element in the interrelated set or system of phenomena specifically constituting the environmental condition in question. Indirect indicators may reflect secondary or consequential interactions within adjoining or encompassing systems. In the complex environmental conditions associated with desertification, for example, an indirect indicator (e.g. worsening nutritional status within a population group) could indicate changing economic status, independent of local environmental conditions and yet linked in a secondary set of consequences to desertification. Similarly, in a time of extreme climatic change (e.g. drought), a nutritional indicator such as stunting and

oedema, is an indication of heightened vulnerability, loss of assets (e.g. livestock, etc.) as well as land-use changes accompanying the drought (poor yields, etc.) Indicators may also be used, in some cases, as predictors of change. Excessive stocking levels on rangelands or continuing below-average rainfall seasons could be predictors of future desertification and land-use and land-cover change.

There are two general classes of indicators that are relevant for LUCC. The first, are indicators of change in land cover. These can be used for detection of change, or to provide information on shifting trends or trajectories in LUCC. The second class relevant to LUCC are indicators of land quality. Such land quality indicators (LQI) are important for informing both the science and policy community about a range of policy-relevant aspects of LUCC - indications as to whether trends are improving in terms of land use and land quality with respect to a given policy or environmental change (such as climate change).

Theme 7: Model inter-comparison

A variety of LUCC modelling approaches are underway internationally, ranging from empirical and observational to integrated and prognostic in kind. Each such effort employs different sets of assumptions and operational mechanisms with implications for model results and, hence, comparisons. To facilitate these comparisons and the understanding of the LUCC community in general, a typology of the applicability of various modelling approaches is required, complete with explication of their intellectual and statistical underpinnings. A review of empirical modelling approaches for LUCC that meets some of these needs is available, but their counterparts for other sectors and for theoretical and integrated modelling efforts found in Themes 1 and 3, do not exist, nor have the linkages and comparisons with the empirical models of Theme 2 been established.

From the outset (refer to IGBP Report #35 and IHDP Report #7) the LUCC community identified the issue of scales (spatial, temporal, and hierarchical) as one of the most important to improved understanding and modelling. Despite the extensive work on spatial scales and modelling by geographers and systems scientists over the last three decades, few attempts have been made to distil the general lessons of coupling, nesting, and crossing scales in a way that is compatible with the "thinking" among non-scalar practitioners (NAS 1997). The importance of such an effort has resurfaced; however, in LUCC and global change science, they have resurfaced more generally as *global to local* and *local to global* linkages, which are becoming increasingly central to the problems undertaken.

Theme 8: Vulnerability and environmental security

Environmental security is a contested concept somewhat akin to sustainability (e.g. Myers, 1986; WCED, 1987; Westing, 1989; Lonergan, 1997). Some suggest that it comprises two interconnected parts: (a) protection against environmental hazards, such as medically unacceptable pollution or El Niño triggered drought, and (b) sustainable or more environmentally benign resource utilization (Westing, 1991). Environmental security, therefore, signifies the array of themes related to impacts and policies of human-environment relations, and differs from the allied notion of human security by limiting security themes to those with an environmental component (IHDP Report #11: "Global Environmental Change and Human Security", 1999).

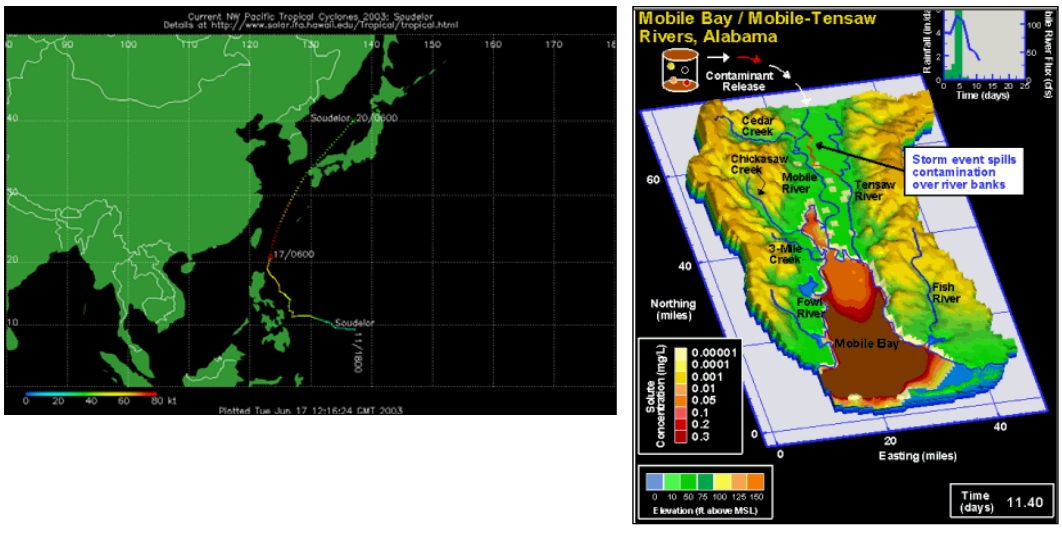


FIGURE 6-2: GIS and Mapping Environmental Security and Vulnerability
Storm Tracking and Mapping Potential Flood Risks

Much previous work associated with environmental security focuses on human-induced environmental hazards, such as environmental degradation as a cause or contributor of human insecurity (e.g., food, health, or sustainable use). Research and policy efforts associated with environmental security (e.g. Lonergan, 1997) include, among others:

- Developing a system to help anticipate future threats which might be triggered by environmental disruptions;
- Identifying adaptation mechanisms and how these mechanisms may be reinforced in vulnerable communities and regions;
- Developing case studies of how environmental degradation influences migration and other human responses; and

- Developing integrated assessment procedures for policies and programmes to ensure assistance does not enhance environmental degradation.

The aforementioned list is broad and reflects the nascent stage of development of environmental security. One aspect of it, however, that has been directly linked to global change is vulnerability (e.g. Liverman, 1990; Downing, 1992; Downing, Watts and Bohle, 1996). Vulnerability is an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of potentially harmful threats (Downing, 1992). Such aggregation, however, is sensitive to how different groups in society experience risk and mitigate hazards (e.g. Downing, Watts and Bohle, 1996). One cluster of vulnerability research initiatives aims to identify and examine global climate change impacts on society, especially in terms of impacts on food security and livelihood security. Central to this theme is sector-specific vulnerability and household resilience to climate change. Increasingly, vulnerability research has shifted from an assessment of food security and food relief in times of disaster to an understanding of the longer-term connections between vulnerability and patterns of natural and human-induced risk. Endowments, class relations, empowerment, and political ecology are analytical concepts that have been used to capture such an understanding of vulnerability in some cases (e.g. Canon, 1994; Liverman, 1990; Kasperson, Kasperson and Turner, 1995, Downing, Watts and Bohle, 1996).

A key area of research is the link between the composition of household livelihood strategies and how these are and how they might predispose communities to risk. Understanding the causal structure of present vulnerability enables the documentation and analysis of vulnerable groups over the next few decades and provides a baseline against which to measure the possible impacts of future climate change events (Downing, Watts and Bohle, 1996; Davies, 1996).

Recent results based on such approaches in Africa show that despite the high risk associated with maize cultivation in Zimbabwe and Lesotho, there has been little shift in behaviour to more drought-resilient cereals (e.g. Eilerts and Vhurumuku, 1997). Utilization of wild foods, moreover, contrary to popular belief, also made relatively unimportant contributions to household diets during periods of climate stress. Rather than employing coping strategies during periods of drought, households adopted such strategies as increasing the income from their normal livelihood strategies and seldom initiate new ones (e.g. Vogel, 1994; Save the Children Fund UK, 1995; World Food Programme, 1996; Eilerts and Vhurumuku, 1997; Eldridge, 1997). These responses to periods of climate stress (such as drought) have obvious land use implications for long-term climate change as well as to a myriad of environmental changes.

The inclusion of vulnerability linked to environmental security within the IGBP/IHDP LUCC Core Project research foci is as timely and essential as it was anticipated. The integration of food security, heightened risk and vulnerability to sustainable development and effective natural resource management are themes

that cross cut each foci, link to the IHDP's initiative on environmental security and complement various policy initiatives. LUCC research is especially suited to contribute in various ways to this theme.

Theme 9: Science for human and national needs

A spin-off science is the development of the social and environmental implications of the various trajectories of land-use and land-cover change. The aim here is to glean the lessons from comparative case studies and modelling efforts. It is difficult to identify in advance which consequences will emerge as robust but examples include the distributive (e.g., resource rights, land tenure), population-migration, health, and gender as well as the cumulative environmental (e.g., long-term landscape changes) consequences of land-use and land-cover change and its trajectories.

In some cases this distillation overlaps with other activities, such as vulnerability and environmental security. In this example, all of the potential outputs of that

FIGURE 6-3: Food Vendor in Hanoi, Viet Nam

activity involve the social and environmental lessons drawn from the case studies and modelling exercises. Some of the critical components that should be addressed are listed as follows:

LUCC and human health: The field of health operates with a series of assumptions about the impacts of land-use and land-cover change and the IGBP/IHDP LUCC Core Project needs to provide substance to them. Critical themes involve disease eradication, vector borne disease, the distributive properties of land-use and land-cover change on disease, and the evolutionary behaviour of diseases in changing landscapes.

FIGURE 6-4: Harvesting Upland Rice, Ratanakiri, Cambodia

LUCC and food production and availability: In a world projected to have 10 billion inhabitants striving to consume at higher levels, food production and availability (often coined food security) is of prime concern. Various assessments question the course of technology and food production on average for this rapidly approaching world, while others call into question the role of food distribution as the most serious issue. The two, of course, operate in tandem and are intimately linked to land-use and land-cover change. The various regional studies in LUCC lend important insights into the nature of food production and availability in various places, and these need to be elucidated and made available to the community in question.

LUCC and migration/circulation: Land-use and land-cover change affects migration and circulation and, in turn, is affected by them. Despite the attention given to these linkages, such as the many studies of remittances to rural households, no clear patterns of relationships have yet been established. The literature might be interpreted to imply that these relationships are variable by region, and they might be. Yet, little in the way of exhaustive, comparative assessments has been made to date. Most LUCC case studies include the role of migration as do the modelling exercises. The LUCC-migration relationship, therefore, should constitute a major lesson-drawing activity.

LUCC and urbanization: Urbanization is a global phenomenon, giving rise to large metroplexes throughout the world. Such conditions have important implications for land-use and land-cover change in at least three ways:

- Urban expansion often consumes prime agricultural land or affects use on the peri-urban fringe through speculation;
- An increasing proportion of urban population suggests increased levels of consumption, both within the urban population and through influences on the rural population, and hence increased demands on production; and
- Industrial production and consumption can lead to tropospheric pollution in adjacent lands (hundreds of km away) with impacts on cultivation. LUCC case studies and modelling shed light on these themes. [Heilig, 1995]

FIGURE 6-5: Bangkok, Thailand

LUCC and property and resource allocation issues: Land-use and land-cover change affects and, in turn, is affected by the institutions (rules) governing access to land and resources (e.g., water). The competing views in the research community are many, for example arguing that efficient intensification and private property or social equity and common property are intimately linked. Comparative work suggests more complex patterns of relationships in which, for example, the role of private property and intensification are conditioned by a larger structure in which they take place. Likewise, the creation of national parks and biosphere reserves throughout the developing countries raises serious issues about the land use dynamics surrounding them. These and other property and resource allocation issues require comparative understanding in order to uncover under which conditions different trajectories of relationships might arise.

Theme 10: LUCC regional assessments

Land use in a changing environment presents policy-makers and planners with a large diversity of possible options, pathways and outcomes. The consequences of their decisions might not be immediately obvious due to the considerable uncertainty in the understanding of relevant processes and their interactions and feedbacks, irreversibility and non-linear character, and the involvement of many different temporal (seasonal, inter-annual and long-term), spatial (from field to globe) to societal scales (farm, village, country, region). This uncertainty is inherent in the complexity of the dynamics of the LUCC system.

Comprehensive analyses of land use possibilities, and their dynamics and consequences, requires an integrative framework that completely covers the diverse aspects. LUCC aims to enhance the understanding of cause-use-cover dynamics to improve local, regional and global assessments. Such assessments should be able to:

- Combine knowledge and understanding from a wide range of disciplines;
- Link natural and human systems;
- Link LUCC dynamics at local, regional and global scales;
- Explore historical and future trajectories of these systems;
- Assist in defining research priorities; and
- Be relevant for policy formulation.

The specific requirements for a LUCC assessment depend on their objective. Evaluating environmental or food security requires a different emphasis than those for climate change, human health or biodiversity. Although components can be different for each specific assessment, they should all include a minimum set of common elements. For example, adequate LUCC assessment should include both conversion and modification (or degradation) of natural vegetation and agricultural lands should be geographically sufficiently disaggregated to allow for LUCC dynamics and sensitive to important driving forces of change. Such a framework should allow for an unrestricted applicability at all scales relevant to LUCC dynamics, and emphasize the fundamentally continuous, interactive nature of these dynamics.

Simply analysing data and modelling at multiple scales is a way of addressing scales without crossing them. Simple aggregation strategies are not adequate in capturing the bottom-up and top-down dynamics. The overarching aim of the IGBP/IHDP LUCC Core Project is to couple qualitative models at the scale of case studies (Focus 1) with regional thematic models (Focus 2) and to couple regional models of change with global models (Focus 3). The coupling involves aggregation and disaggregation at the appropriate levels and should address the characteristics of LUCC dynamics at different scales.

LUCC can undertake two kinds of assessments. The first would be to provide regular assessments on state-of-the-art LUCC research, indicating what is known

and what is not. Identification of uncertainties would provide input into the development of new research thrusts and would inform the policy- and decision-making communities. This kind of assessment can be routinely done through regular synthesis workshops, and through regular inventories of LUCC research. To implement the inventory of LUCC research a process can be developed at the International Programme Office of the IGBP/IHDP LUCC Core Project to identify existing projects, programmes, people and institutions involved in LUCC research. This would, in turn, provide inputs to the funding process of IGFA.

The second type of assessment would be associated with integrated environmental assessments, taking into account the role of LUCC. Much effort has been placed on the development of climate related integrated assessment and it would also be important to begin to take a similar approach with respect to LUCC. This would draw from the work done in vulnerability studies and would also include the integrated modelling efforts developed in Focus 3 of the IGBP/IHDP LUCC Core Project as linked to specific questions and/or policy issues. A range of issues need to be considered in light of LUCC impacts as related to the *interaction* between climate change and LUCC, human health, food security, land quality, and land distribution issues. Also, routine assessments, or *report cards*, need to be developed which evaluate trends - including inter-annual variability - in key variables and their controls. The instruments for making such assessments could be developed in direct collaboration with Institutions conducting integrative assessments and/or through regular workshops.

One first step in this regard could be to focus on LUCC model inter-comparison studies. As more LUCC models from any of the three Foci outlined by the IGBP/IHDP LUCC Core Project become established, it would be useful to evaluate their sensitivities, uncertainties, range of outputs, and performance relative to each other and relative to specific questions or applications. Regular model inter-comparison workshops would also be instrumental. These efforts are often difficult and expensive and there would need to be strong institutional support for such an endeavour. Common datasets would also need to be developed.

7 Closing

In the time between the workshop activities that took place at the APN Secretariat in September, 2002 and the publication of this *Initial Synthesis*, many developments have been made in the projects outlined in this report and a number of the projects are ongoing with continued APN support.

Furthermore, while the previous Section (6) focuses on ways forward for LUCC research in the region of Southeast Asia, readers of this *Initial Synthesis of Land-use and Land-cover Change Research in Asia and the Pacific* are highly encouraged to visit the APN website <http://www.apn.gr.jp> for more details on the activities being carried out in the area of LUCC in the Asia-Pacific region. In so doing, readers are also encouraged to look at the IGBP/IHDP LUCC Core Project activities in the Asia-Pacific region as well as the other significant projects and activities outlined in this *Initial Synthesis*.

Appendix

Related APN Projects

99004 Land-use Change and Terrestrial Carbon Stocks: Capacity Building, Impacts Assessment, and Policy Support in South and Southeast Asia

http://www.apn.gr.jp/products/project_report/rep1999/99004.html

2000-01 Land Use/Management Change and Trace Gas Emissions in East Asia

http://www.apn.gr.jp/products/project_report/rep2000/00001.html

2000-02 Land Use/Land Cover Change in Asia and the Carbon Cycle

http://www.apn.gr.jp/products/project_report/rep2000/00002.html

2001-03 Change and Sustainability of Pastoral Land Use Systems in East and Central Asia

http://www.apn.gr.jp/products/project_report/rep2001/01003.html

2001-09 Spatial Data and Information for Land Use and Forest Assessment and Management

http://www.apn.gr.jp/products/project_report/rep2001/01009.html

2001-13 Land Use and Land Cover Change for Southeast Asia

http://www.apn.gr.jp/products/project_report/rep2001/01013.html

2001-17 Global Change Impact Assessment for Himalayan Mountain Regions for Environmental Management and Sustainable Development

http://www.apn.gr.jp/products/project_report/rep2001/01017.html

2002-15 Inventory of Glaciers and Glacial Lakes and the Identification of Potential Glacial Lake Outburst Floods (GLOFs) Affected by Global Warming in the Mountains of the Himalayan Region

http://www.apn.gr.jp/products/project_report/rep2002/02015.html

2002-17 PABITRA Network for Collaborative Research on the Ecology of Global Change in Island Landscapes of the Tropical Pacific

http://www.apn.gr.jp/products/project_report/rep2002/02017.html

Related Websites

APN	http://www.apn.gr.jp/
EOC-UKM	http://www.eoc.ukm.my/
GCTE	http://www.gcte.org/
ICIMOD	http://www.icimod.org.np/
IGBP	http://www.igbp.kva.se/
IHDP	http://www.ihdp.org/
LUCC Core Project	http://www.geo.ucl.ac.be/LUCC/home.html
MA	http://www.milleniumassessment.org/
PABITRA	http://www.botany.hawaii.edu/pabitra/
SEARRIN	http://www.eoc.ukm.my/searrin/
START	http://www.start.org/

Abbreviations & Acronyms

AIACC	Assessment of Impacts and Adaptation to Climate Change
APN	Asia-Pacific Network for Global Change Research
ASALS	Arid and Semi-Arid Lands
BPPT	Agency for the Assessment and Application of Technology
BTIC	BIOTROP Information Center
CDM	Clean Development Mechanism
DIVERSITAS	International Biodiversity Research Programme
DIWPA	DIVERSITAS in Western Pacific and Asia
EOC-UKM	Earth Observation Centre, Malaysia

EIS-Africa	Network for Environmental Information Systems in Africa
ESA	Earth Science Applications Directorate, NASA
ESSP	Earth System Science Partnership
FAO	United Nations Food and Agriculture Organization
GCTE	Global Carbon Terrestrial Ecosystem
GIS	Geographic Information Systems
GISD	Geographic Information for Sustainable Development
GEF	Global Environmental Facility
GLOFS	Glacial Lake Outburst Floods
GOFC-GOLD	United Nations' Global Observation of Forest and Land Cover Dynamics
IAI	Inter-American Institute for Global Change Research
ICIMOD	International Centre for Integrated Mountain Development
ICSEA	Global Change Impacts Center for Southeast Asia
IGBP	International Geosphere-Biosphere Programme
IGFA	International Group of Funding Agencies for Global Change Research
IHDP	International Human Dimensions Programme
IIASA-LUC	International Institute for Applied Systems Analysis - Land-Cover Changes
IPCC	Intergovernmental Panel on Climate Change
ITC	International Institute for Geo-information Science and Earth Observation
LAPAN	Indonesian Space and Aeronautics Institute
LCCS	Land Cover Classification System
LUCC	Land-use and Land-cover Change[5]
LUTEA	Land Use in Temperate East Asia
MA	Millennium Ecosystem Assessment
MEDIAS-France	Governmental Non-Profit Organization for Research Development on Global Change particularly in the Mediterranean Basin and Subtropical Africa
MRI	Mountain Research Initiative
PABITRA	Pacific Asia Biodiversity Transect
PSA	Pacific Science Congress
SEARRIN	Southeast Asia Regional Research and Information Network
SEA-SPAN	Southeast Asian Science-Policy Network
SARCS	Southeast Asia Regional Committee for START
START	Global Change SysTem for Analysis, Research and Training
TEACOM	Temperate East Asia Regional Committee for START
UNFCCC	United Nations Framework Convention on Climate Change

[5] The term "**LUCC**" stems from the **LUCC Core Project of IGBP and IHDP**

UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
WCRP	World Climate Research Programme
WSSD	World Summit for Sustainable Development

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