FINAL REPORT for APN PROJECT
ARCP2009-06CMY-Braimoh

Managing Ecosystems Services in Asia: A Critical Review of Experiences in Montane Upper Tributary Watersheds

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

Human well-being depends on the maintenance of ecosystem services. Upper tributary watersheds provide diverse services such as water provision, soil renewal for agriculture, mitigation of floods, groundwater recharge, soil erosion control, nutrient abatement and carbon sequestration. However policy-makers have found it hard to find ways of incorporating the benefits derived from ecosystem services into decision making. One reason is the difficulty of characterizing ecosystem services in a manner that policy makers can use it. Another is the challenge of negotiating accountable systems of governance and compensation. Several promising but still insufficiently tested governance mechanisms are being explored, for example, payments for ecological services. All approaches need to consider costs and other disadvantages or risks of ecosystem services conservation to various user groups, and trade-offs intrinsic to ecosystem maintenance. This project addresses these pertinent issues by reviewing experiences across a wide range of projects and illustrating solutions and their limitations through three in-depth case studies in China, Indonesia and Thailand.

Objectives

The main objectives of the project were:

1. Develop a framework for analyzing Ecosystem Services
2. Analyze governance structures vis-à-vis the delivery of Ecosystem Services
3. Identify trade-offs and incentives for Ecosystem Services conservation

Amount received and number years supported

The APN Grant awarded to this project was:
US$ 45,000 for Year1, 2008-2009
US$ 45,000 for Year 2, 2009-2010

Activity undertaken

Activities undertaken included

1. Critical reviews about land-use, vegetation and climate impacts on biodiversity and ecosystem services; and (b) institutional mechanisms, such as payment for ecosystem services, community-based management and watershed policies to maintain services from upper tributary watersheds.
2. Three case studies of ecosystem services management in China, Indonesia and Thailand
3. Workshops to synthesize findings and profer policies for sustainable land management

Results

Our review of climate and land use impacts documents the biophysical characteristics of Southeast Asia, provides an account of the current state of biodiversity in the region and analyzed biodiversity loss vis-à-vis climatic and anthropogenic drivers with special attention to deforestation and habitat loss. Prominent anthropogenic influence on biodiversity includes biofuel production, trade, land tenure systems and urbanization. Policy responses that can curb biodiversity decline in the region include monitoring and regulation, sustainable land management and a host of other mitigation and adaptation measures.

Our review of institutional mechanisms indicate that communities, governments and firms have taken different approaches to prioritizing, negotiating and sharing benefits, as well as dealing with trade-offs between them including spatial land-use planning, delineation for biodiversity conservation, watershed protection, forestry, agriculture, tourism or multiple uses. Institutional instruments include quotas, licenses, concessions, seasonal bans as well as other customary rules, taboos and norms. Market-based instruments or other forms of incentives which reward good management practices include payments for environmental services and certification schemes. Raising awareness of ecosystem services through education, support can be gained for their conservation.

In the Thailand case study, we explored the efforts of different stakeholders to manage ecosystem services provided by the Mae Hae watershed with particular attention to the interactions between technological innovations, social institutions and ecosystem conditions. The watershed has under gone substantial changes in the last four decades as a result of, successful opium substitution programs led by the Royal Project and increasing commercialization of production of temperate crops in the dry season. Almost half of the households felt forest cover had declined in their part of the watershed, whereas 12% thought it had increased. The amount of forest products present was judged to have declined by most households. More than half of households in Mae Hae usually experienced water shortages in at least one month with shortages most likely between March and May. Self reported trends in availability of water indicate substantial shifts in the past five years with less water being available at end of dry season and more towards the end of the wet season. Using logistic regression, we investigated the households that were more likely to face water shortages. There was no significant association with low household income, household size or ethnicity. Households that use sprinklers are twice as likely to face shortages as those who do not.

A study of the impact of agricultural land change on biodiversity and ecosystem services was carried out in Bawan Village, located about 60 km northeast of Palangkaraya in Central Kalimantan, Indonesia. Most of the area is covered mainly by heath forest, with scattered patches of peat swamp forest. From 1968 until 1980s, private forest concessions were rampant leading to wood and rattan exploitation. For easier accessibility, forest concession companies built a road for transporting forest products to the nearest river, from where they were delivered by boat downstream. This forest concession led to the degradation of the forest ecosystem and consequently affected the livelihoods of the local people (Dayak). Before 1980s, the main source of income to the local people was from the manufacture of small boats and wooden house rooftops, with supplemental revenue derived from agriculture. After the period of forest concession, Bawan villagers converted the clear-cut area to rubber plantation. Rubber cultivation in the area has expanded to some 1100 ha by 2008. This expansion has influenced microclimate, biodiversity and water resources. The poor quality of the Kahayan River due to various human activities has made the people to shift to consuming water from a spring located about 3 km from the village. Deforestation also increased river sedimentation, thereby increasing flood frequency. Biomass analysis indicates that heath forest conversion results in about 73.78 t ha^{-1}carbon emission from the above ground biomass, reflecting enormous carbon sequestration potential from land use systems that conserve forest. There is a need to develop such land use systems that not only benefits the environment, but also improves the livelihood of the local community.

The Supa River Watershed, a tributary of Nu-Salween River, integrates agricultural production with biodiversity conservation and hydropower development. Different ecosystem services have different providers and beneficiaries. Xiaoheishan Nature Reserve maintains biodiversity, which benefits the entire society. It is fully subsidized by the government and the nature reserve unit is responsible for its management. The collectively owned woodlands and some upland play decisive roles in conservation of water and soil, which benefit the farmers and the hydropower company. Both the government and the villagers have made contributions to maintain eco-system services. The hydropower company also pays water royalty and is willing to invest in maintenance of ecosystem services, but it is necessary to explore and find out a sustainable mechanism to do so. Our study showed that local farmers are very positive about environmental conservation. Since the Supa River Watershed started the Sloping Land Conversion Program, the local farmers have received high incentives and actively converted upland areas in continuous parcels to forest. Many village communities organized to conduct uniform management of collectively owned forests, developed very good systems and raised funds and hired farmers for management. In Longxin Township, for example, about 60% of village communities organized and conducted uniform management and the villager invested 0.15 million RMB to the tending costs per year. The hydropower company benefited from eco-system services but has not contributed enough to the maintenance of ecosystem values. It argues that it is government responsibility to protect the environment after it has paid its statutory company tax. However, just like any other infrastructure, the functions of ecological services also need investment. The tax and water resources fee paid by the company is the social obligation that any company must perform and is a compensation for occupation and use of public resources. It should not release the company's responsibility for environmental protection. Ecosystem value did not effectively influence policy although it is a useful approach to understand the importance of ecosystem to human beings. Stakeholders in the Supa Watershed recognized the scientific evidence of ecosystem services valuation. It is difficult however to reach an agreement on maintenance of ecosystem when stakeholders had a dialogue on possible solutions. Without regulation, payment for environment services will be on a voluntary basis.

An indicator-based integrated assessment of ecosystem change and human-wellbeingwas also carried out with case studies from Supa Longling in China, Bawan village in Indonesia and Kushiro in Japan. A multi-stakeholder PRA approach was utlised to capture revealed preferences and values that the ecosystem services hold to the different stakeholders who gain utility from them. We observed that the process serves provides a better representation of the preferences of different stakeholders of ecosystem services, fosters validation of data between the different stakeholders and enables a communication and planning process among the stakeholders to sustainably utilize and manage their ecosystems. The use of spatial maps validates the relevance and utility of diachronic observations of communities and other stakeholders directly dependent on ecosystems. At the same time, they can be used to strengthen local planning processes for the development of services in the ecosystem, of relevance to humans and nature. Such research thereby also acts as a catalyst to a social process of coordinated action to address local issues of global relevance

In an attempt to examine whether insights on land change dynamics at the local level are applicable at the national level as well, we mapped deforestation at the national level in Thailand, Malaysia and Indonesia, estimated C stock, and related land-cover changes to elevation, GDP and population using linear multiple regression. Total area of under forest cover as estimated by remote sensing was 161.64 and 137.35 Million ha (Mha) in 1990s and 2000s, respectively, indicating a forest cover net loss of 15%. The net change was about 8% for Malaysia, 10% for Thailand and 17% for Indonesia. Conversion of forest to croplands is the highest land-cover change category for the countries. Forest cover loss has a negative relation with population and a positive relation with GDP, in particular for Indonesia. A higher population in the largely agrarian region results in an increase in demand for food, causing large proportion of forest cleared and used for crop cultivations to meet food needs. The model results for forest gain indicates a negative relationship with population, but a positive relationship with GDP for all the countries with the highest coefficient for GDP for Malaysia. This is not unconnected with the growth of urban markets that led to abandonment of agricultural land.

In the 1990s, total terrestrial C ranged from 10 billion tons for Thailand to 97 billion tons for Indonesia. By the 2000s, Indonesia and Malaysia experienced about 25% decline in C whereas Thailand lost about 18% of its terrestrial C. This loss is equivalent to amounts ranging from $57 billion for Thailand to $780 billion loss for Indonesia. The damage due to Cemissions from deforestation on the landscape can be up to $15,350 per hectare depending on the type of forest converted. The carbon maps provide information on parts of the landscape where reforestation is required and the social benefits ensuing from such conservation programs.

Relevance to APN's Science Agenda and objectives

This project contributes to APN's Scientific Agenda by improving understanding of the impacts of land management on biodiversity and ecosystem services provided by upper tributary watersheds. The collaborative, institutional and policy-oriented research and synthesis activities in Thailand, Indonesia and China will help facilitate informed environmental policy and practice. In particular, the project's reviews and illustrative case study research provide useful policy insights into how to enhance long-term sustainable use and conservation of services in Southeast Asia. Through its participatory orientation, the project also fosters interaction among scientists, resource users and policymakers.

Self evaluation

All the objectives set at the onset of the project were met.

Potential for further work

The findings can be broadened to assess simulataneous provision of multiple ecosystem services and the inherent tradeoffs. The study can also guide in depth anlaysis of REDD+ and Biodiversity and specific intervention points for equitable distribution of ecosystem services amongs different stakeholders.

Publications

Braimoh, A.K., Suneetha, M.S., Elliott, W.S. and Gasparatos, A. 2010. Climate and Human-Related Drivers of Biodiversity Decline in Southeast Asia. UNU-IAS Report scheduled for COP 10 Meeting, Nagoya.

Braimoh, A.K., Agboola, J.I. 2009. Strategic Partnership for Sustainable Management of Aquatic Resources Water Resource Management, 23:2761–2775.

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Lebel, L., Daniel, R. 2009. The governance of ecosystem services from tropical upland watersheds. Current Opinion in Environmental Sustainability, 1:61–68.

Lebel, L. and Daniel R.. Governing ecosystem services from upland watersheds in southeast Asia. In Braimoh A.K. and Huang, H.Q. (eds). Vulnerability of Land Systems in Asia (in preparation)

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TECHNICAL REPORT

Preface

This report provides an account of the current state of biodiversity in Southeast Asia and analyzes biodiversity loss vis-à-vis climatic and anthropogenic drivers with special attention to deforestation and habitat loss. It also includes a review of ecosystem services management mechanisms including spatial land-use planning, delineation for biodiversity conservation, watershed protection, forestry, agriculture, tourism and multiple uses. Case studies in China, Indonesia, and Thailand inventorize and conduct a valuation of ecosystem services based on a multi-stakeholder perspective, model deforestation and terrestrial carbon and provide policy insights into enhancing long-term sustainable use and conservation of services from ecosystems in Southeast Asia

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Chapter 1

Climate and Human-Related Drivers of Biodiversity Decline in Southeast Asia

Ademola K. Braimoh, Suneetha M. Subramanian, Wendy S. Elliott and Alexandros Gasparatos

1. Introduction

Southeast Asia has been recognized as a bio-cultural hotspot. The region hosts diverse biological resources and cultural milieus that are under different degrees of stress due to a variety of factors. This report highlights the key underlying economic, political and natural factors that contribute to biodiversity[1] decline in the region, and provide some specific policy directions that could help address these underlying factors.

Section 1 documents concisely the biophysical characteristics of Southeast Asia. Section 2 gives an account of the current state of biodiversity in the region and presents a framework for analyzing biodiversity loss vis-à-vis climatic and anthropogenic drivers with special attention to deforestation and habitat loss. Section 3 further covers prominent anthropogenic influence on biodiversity including biofuel production, trade, land tenure systems and urbanization. The impacts of climate and its interaction with other drivers are discussed in Section 4, followed by policy responses that can curb biodiversity decline in the region in Section 5.

1.1 Background

Southeast Asia extends from Latitude 10° S and 30° N, and stretches between Longitude 90° W and 140° E (Figure 1). It comprises 11 countries with a combined population of over 565 million (Table 1).

The region exhibits marked variation in elevation ranging from 100 m below sea level to over 5000 m above sea level in the mountains of Southwest China[2]. Outstanding diversity in terms of land use, species and habitat can be found in the montane regions. These areas have most of the region's remaining forests, whereas the lower regions are composed of a mix of agroforestry landscapes.

About 72 percent of the population lived in the rural area in 2000, but due to rapid urbanization about half of the population is predicted to inhabit Southeast Asian cities by 2025. This growing urban population is to a large extent responsible for the rapid economic development in the area. However, this economic development is accompanied by considerable exploitation of natural resources, including forest resources, leading to significant environmental degradation.

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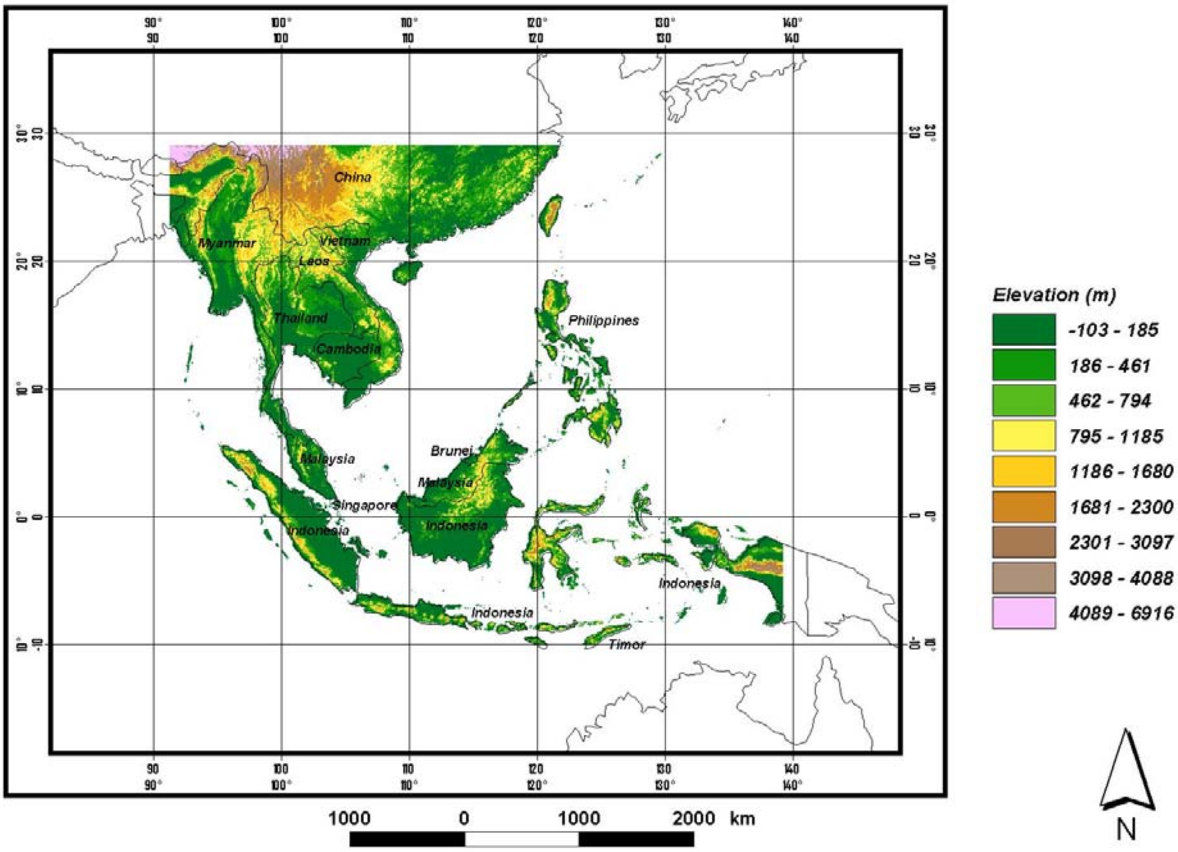
[1] In this report, biodiversity or biological diversity is defined as diversity in genetics, population, species and the ecosystem.

[2] Many studies include Southwest China as part of Southeast Asia. In this report we limit our definition of Southeast Asia to mainly the 11 countries in Table 1.

Figure 1: Physiographic map of Southeast Asia



Elevation data was obtained from http://glcf.umiacs.umd.edu/ (accessed on 2 May 2010).

Table 1: Land area and population of Southeast Asia

Country	Land Area (1 000 ha)	Forest cover (%)	Percent annual rate of forest change (2000-2005)	Population in 2006 (1 000)	Percent Urban population (2000)	Percent Urban population (2025)	Human Development Index rank (2006)
Indonesia	181 157	49	-2.0	228 864	42	51	111
Philippines	29 817	24	-2.1	86 263	48	55	105
Vietnam	31 007	40	2.0	86 205	24	41	116
Thailand	51 089	28	-0.4	63 443	31	42	87
Malaysia	32 855	64	-0.7	26 113	62	81	66
Myanmar	65 755	49	-1.4	48 379	28	44	138
Singapore	69	3	0.0	4 381	100	100	23
Cambodia	17 652	59	-2.0	14 196	17	26	137
Laos	23 080	70	-0.5	5 759	22	49	133
Timor-Leste	1 487	54	-1.3	1 113	24	36	162
Brunei Darussalam	527	53	-0.7	381	71	81	30
South East Asia	**434 495**	**47**	**-1.3**	**565 097**	**38**	**50**	**-**

Data sources: FAO State of the World's Forest 2009 (http://www.fao.org/docrep/011/i0350e/i0350e00.htm); World Urbanization Prospects 2009 Revision (http://esa.un.org/unpd/wup/index.htm); and the UN Human Development Report 2009 (http://hdr.undp.org/en/)

1.2 Climate Patterns and Variability

The high mountains and the complex land-sea configuration of Southeast Asia have a strong influence on weather and climate. Three distinct rainfall regimes can be identified across the Southeast Asian region (Kripalani and Kulkarni, 1998; Table 2). A substantial proportion of the annual precipitation over most of the region is received during the summer period of the northern hemisphere.

Table 2: Major characteristics of the three rainfall regimes of Southeast Asia in comparison to the northern hemisphere seasons

Rainfall regime	Description	Major characteristics	Countries/Areas
Asian Monsoon Region	Continentality with high mountains is the contributor to enhancement of summer monsoon	High precipitation (maximum of 1150mm in July) on the western slopes and along Myanmar-Thailand frontier as a result of orography and the Southwest monsoon laden with moisture from the Bay of Bengal. In areas 20 – 25 degrees N, appreciable rainfall (300 – 500mm) is observed during summer monsoon months due to the Inter-Tropical Convergence Zone (ITCZ). In the autumn, the Vietnam coast receives maximum rainfall of 550mm in October due to winter atmospheric circulation, whereas there is a marked decrease in rainfall from July to October over the Arakan coast.	Myanmar, Thailand, Vietnam, Laos, Cambodia
Equatorial Monsoon Region	This region is influenced by the North Australian-Indonesian monsoon regime. The continent ocean-heat contrast makes it the strongest component of the southern hemisphere circulation.	Areas around Malaysia, Brunei and Sulawesi receive more rain during northern winter, while for areas between Latitude 110° – 120°E, the northwest winds during the southern summer monsoon bring more rainfall (500 – 700 mm). The region lying between the Equator to Longitude 5°S between Sulawesi and New Guinea receives relatively high precipitation during the northern summer monsoon period in July. The movement of the ITCZ in the equatorial zone also causes rain to fall in spring (April) and autumn (October).	Singapore, Malaysia, Indonesia, Sumatra, Timor-Leste, Borneo and Brunei
Pacific Monsoon Region	This region is subject to the influence of Western North Pacific Monsoon regime with less significant continentality.	The maximum rainfall on the northwest coast is attained during the moisture-laden southwest monsoon in July, whereas the maximum rainfall of the east coast is attained during the northeast monsoon blowing from the Pacific.	Philippines

Synthesized from Kripalani and Kulkarni (1998)

The primary source of inter-annual variability in climate in Southeast Asia is the El Nino-Southern Oscillation (ENSO) phenomenon. ENSO results from the interaction between large-scale ocean and atmospheric circulation processes in the equatorial Pacific Ocean. There is a correlation between ENSO and precipitation anomalies in Southeast Asia. Precipitation associated with warm ENSO events (El Nino) tend to be below normal with a larger range of variation, whereas that associated with cold events (La Nina) tend to be above normal with a smaller variation range (Xu et al., 2004; Kripalani and Kulkarni, 1997).

Recent studies indicate that between 1955 and 2007, annual mean maximum and minimum temperatures increased by 0.17 degrees C per decade and 0.24 degrees C per decade respectively over the Asia Pacific region (Choi et al., 2009). These increases surpassed the warming rate of global mean surface temperature (0.13 ± 0.03 degrees C per decade) between 1956 and 2005 (IPCC, 2007). The rate of increase in minimum temperatures is generally greater than that of maximum temperatures (Table 3)

Table 3: Linear trends (degrees C per decade) in maximum and minimum temperatures in Vietnam, Thailand and Malaysia.

Countries	Maximum temperature			Minimum Temperature		
	Winter	Summer	Annual	Winter	Summer	Annual
Vietnam	0.250	0.187	0.242	0.273	0.178	0.206
Thailand	0.161	0.203	0.164	0.559	0.261	0.361
Malaysia	0.192	0.162	0.157	0.236	0.255	0.230

All the trends are significant at the 95% level (Choi et al., 2009)

Significant changes in annual, seasonal maximum and minimum temperature means are associated with changes in frequency of extreme temperature events in the Asia Pacific Region (Choi et al., 2009). Between 1955 and 2007, average frequency of cool nights decreased by 6.4 days/decade, whereas that of cool days decreased by 3.3 days per decade. On the other hand, the frequency of warm nights increased by 5.4 days per decade whereas that of warm days increased by 3.9 days per decade over the same period. Further analysis by Choi et al. (2009) indicate that the rate of change of the frequency of warm and cool days and warm nights has accelerated considerably since the late 1980s, whereas the frequency of cool nights has decreased more or less linearly since the mid-1950s. The strongest changes in extremes are observed in northern tropical regions including Malaysia and Thailand, where the maximum decrease rate in annual frequency of cool nights amounts to -22 days per decade, and the maximum increase rate of annual frequency of warm nights rises to 25 days per decade.

Unlike temperature, seasonal and annual precipitation in Asia Pacific does not manifest spatially coherent trends. Whereas there are linear trends in annual and seasonal total precipitation between 1955 and 2007, these trends are not statistically significant. The increase in seasonal total precipitation is largely due to increases in intensity of rainfall events (Choi et al., 2009). Summarily, the seasonal shifts in weather have exposed the region to annual floods and droughts.

1.3 Future Climate of Southeast Asia

Table 4 summarises the Intergovernmental Panel on Climate Change (IPCC) projections on the likely increase in seasonal surface air temperature and percent change in seasonal precipitation for Southeast Asia using 1961 to 1990 as the baseline period (IPCC). The data suggests an acceleration of warming and more uncertain changes in precipitation during the 21st century. An increase in the occurrence of extreme weather events including heat-wave and intense precipitation events is also predicted for South-East Asia (IPCC, 2007). Sea-level rise, floods and droughts will continue to impact the livelihood of the people. Knutson and Tuleya (2004) predict an increase of 10% to 20% in tropical cyclone intensities for a rise in sea-surface temperature of 2°C to 4°C relative to the current threshold temperature in East Asia, South-East Asia and South Asia.

Changes in climate directly affect material fluxes and the temperature regimes at which chemical transformations occur. In addition, changes in extreme temperature events as well as monsoonal shifts in climate patterns have begun to have dramatic effects on natural resource based economies of the region (Talaue-McManus, 2001).

Table 4: Projected changes in surface temperature and precipitation for Southeast Asia (IPCC, 2007)*

Months	2010 – 2039				2040 – 2069				2070 – 2099			
	Temperature (degree C)		Precipitation (%)		Temperature (degree C)		Precipitation (%)		Temperature (degree C)		Precipitation (%)	
	HFE	LFE	HFE	LFE	HFE	LFE	HFE	LFE	HFE	LFE	HFE	LFE
Dec – Feb	0.86	0.72	-1	1	2.25	1.32	2	4	3.92	2.02	6	4
Mar – May	0.92	0.80	0	0	2.32	1.34	3	3	3.83	2.04	12	5
Jun – Aug	0.83	0.74	-1	0	2.13	1.30	0	1	3.61	1.87	7	1
Sep – Nov	0.85	0.75	-2	0	1.32	1.32	-1	1	3.72	1.90	7	2

* HFE = highest future emission trajectory scenario; LFE = lowest future emission trajectory

2. Biodiversity in Southeast Asia: State and Drivers of Decline

2.1 Global Trends

Currently, global biodiversity is changing at an unprecedented rate and scale in response to human-induced perturbation of the Earth System. Fossil records indicate that the background extinction rate (that is Pre-Industrial value) for most species is 0.1 – 1 extinctions per million species per year. Over the past years however, the species extinction rate has increased to more than 100 extinctions per million species per year (MA, 2005). There is a strong linkage between biodiversity loss and human-driven ecosystem processes from local to regional scales.

In spite of the commitment of Governments in 2002 to curtail the rate of biodiversity loss by 2010, virtually all regions of the world are currently experiencing alarming rates of biodiversity decline (GBO, 2010[3]). Notwithstanding some policy and management response successes, there have been severe declines in population trends of vertebrates, habitat specialist birds, shorebird populations,

[3] Secretariat of the Convention on Biological Diversity, 2010, Global Biodiversity Outlook 3, Montreal.

and extent of forest and mangroves as pressures on biodiversity increase across world regions (Butchart et al., 2010).

2.2 State of Biodiversity and Biodiversity Hotspots

Southeast Asia is one of the most biodiverse regions of the planet. Even though the region occupies just 3 per cent of the world's surface, it accommodates about 20% of all plant, animal and marine species. Southeast Asia includes 3 mega diverse countries (Indonesia, Malaysia and Philippines) and contains 4 of the world's 25 biodiversity hotspots[4] as designated by Conservation International (CI) (Figure 2). Most of the countries in the region fall within the Indomalaysia/Melanesia landmass, categorized as one of the three core areas of biocultural diversity (Maffi, 2007). As such, communities hold a rich germplasm of landraces of various crops. For example, an on-farm/community diversity of crops survey found that rice richness in Vietnam varied from 9 to 74 varieties per community (Jarvis et al., 2008).

Endemicity of plants in these biodiversity hotspots varies from 15% for Wallacea to 66% for Philippines. For example, in the Philippines there are 9,250 vascular plant species with 65.8% endemism, 1000 species of orchids and 165 species of mammals (102 endemic and 47 threatened) as reported by the ASEAN Centre for Biodiversity.

[4] A biodiversity hotspot is a biogeographical region rich in biodiversity but under anthropogenic threat.

Biodiversity hotspot designation is developed to assess global conservation priority. It is based on the criteria that the region must contain at least 1500 species of endemic vascular plants and 70% of its original habitat must have been lost (Myers et al., 2000).

Figure 2: Total number of species and endemism in Southeast Asia.

The bars repre d to endemism of each species (Data source: http://www.biodiversityhotspots.org, accessed on 28 April 2010)

The aforementioned biodiversity hotspots are not the only areas in the region that harbor high biodiversity and high numbers of endangered species. Montane ecosystems throughout the region are particularly noted for the diversity of species that they accommodate (refer to Box 1)

Box 1: Biodiversity of montane ecosystems in Thailand

Several of the upper and lower montane forest habitats in Thailand receive protection as national parks and sanctuaries where subalpine vegetation and varying dominant tree species and forest structure between the eastern and northeastern and southern peninsular regions can be found. Protected areas cover about 20% of land area. However, the ecological services areas face pressures from rural poverty and population migration to mountains, deforestation to cropland, overgrazing and degradation (Thailand 3rd National Report on the Implementation of the CBD, 2006). Overall, in Southeast Asia habitat loss has been characterized as particularly severe (Sodhi and Brook, 2006).

Thailand has 302 species of mammals of which 116 are considered threatened. There are 35 endangered species including the Asian tapir (*Tapirus indicus*) found only in the western and southern mountains of Thailand and the tiger (*Panthera tigrus*) of which only 75 are found in the mountain regions. There are also at least 66 endangered bird species including the Rufous-necked hornbill (*Aceros nipalnesis*) whose habitat in the evergreen forests is being destroyed. There are also about 1,424 threatened plant species with 94 endangered wild species of forest plants several of which are collected for sale and illegal trade (wild animals are also illegally traded) and also face habitat destruction (Thailand Third National Report on the Implementation of the Convention on Biological Diversity, 2006).

Even though a small number of species has actually been extinct from the region, the relatively recent deforestation history and the associated fragmentation of natural habitats is expected to accelerate biodiversity decline in the coming years (Sodhi et al., 2004). Several species native to the area are currently considered as vulnerable (VU), endangered (EN) or critically endangered by the International Union for the Conservation of Nature (IUCN, 2010).

2.3 Drivers of Biodiversity Loss

Sala et al. (2000) recognizes five major drivers of biodiversity loss, namely land use, climate, nitrogen deposition, biotic exchange and atmospheric carbon dioxide. The importance of these drivers varies from one ecosystem to the other. Land-use change (especially deforestation) and climate change generally have the greatest impact for terrestrial ecosystems, whereas biotic exchange is more important for freshwater ecosystems (Sala et al., 2000; Table 5).

Table 5: Impact of a large change in each driver on the biodiversity of selected world biomes by 2100.

Driver	Boreal Forest	Grassland	Savanna	Southern Temperate Forests	Tropical Forests
Land Use	5.0	5.0	5.0	5.0	5.0
Climate	3.5	3.0	3.0	2.0	3.0
Nitrogen deposition	3.0	2.0	2.0	3.0	1.0
Biotic Exchange	1.0	2.0	2.0	3.0	1.5
Atmospheric Carbon Dioxide	1.0	3.0	3.0	1.5	1.0

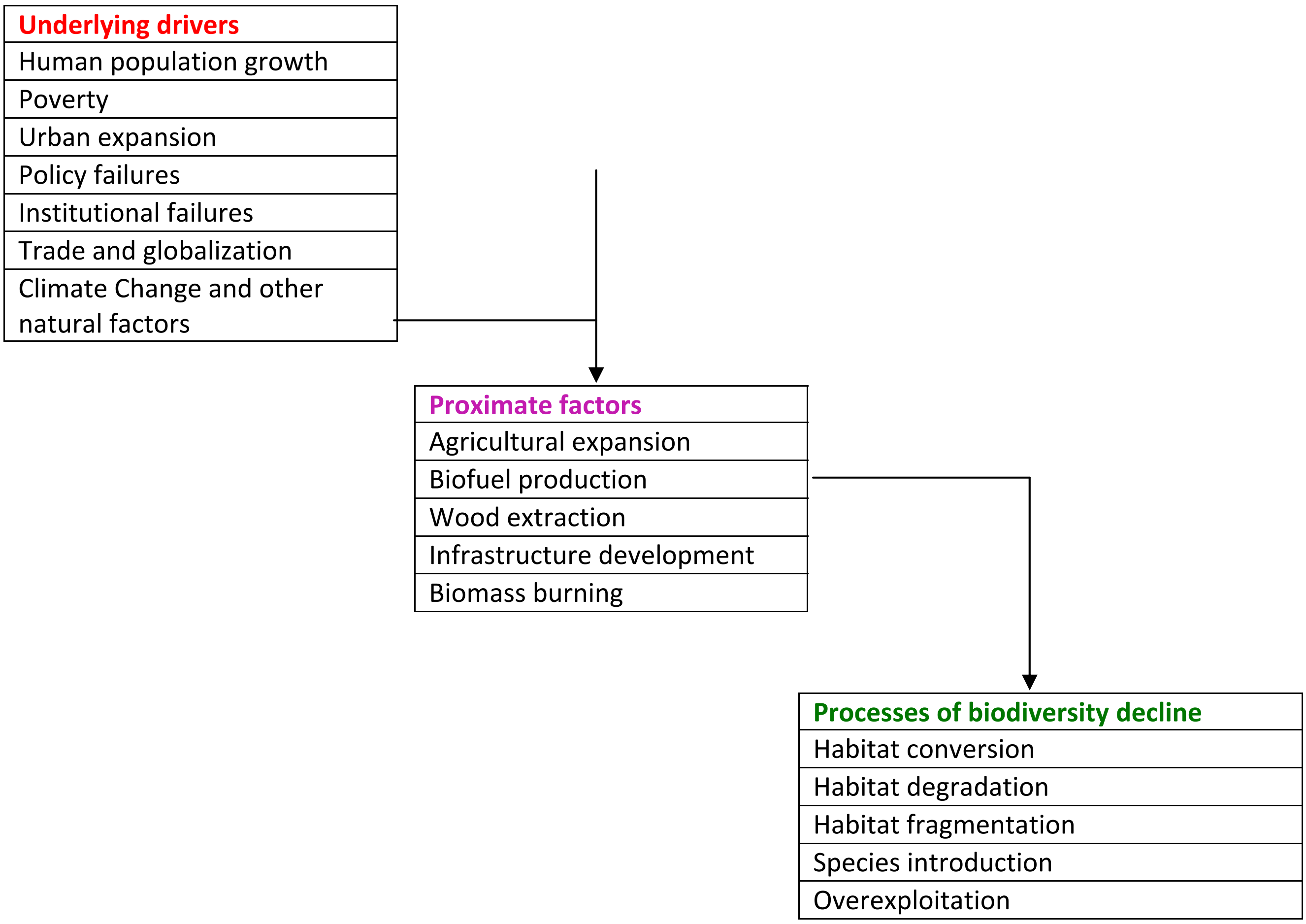
Note: Unit change of the driver was defined for land use as conversion of 50% of land area to agriculture, for climate as a 4°C change or 30% change in precipitation, for nitrogen deposition as 20 kg ha^{-1} $year^{-1}$, for biotic exchange as the arrival of 200 new plant or animal species by 2100, and for CO_2 as a 2.5-fold increase in elevated CO_2 as projected by 2100, Estimates vary from low (1) to high (5) impact based on scenario modeling and expert knowledge (Sala et al., 2000).

A suitable framework for assessing biodiversity decline in Southeast Asia is presented in Figure 3. The framework recognizes that the processes of biodiversity loss are driven by a combination of proximate factors and underlying drivers. Proximate causes are near final or final human activities (e.g. agricultural expansion) that directly affect the environment, whereas the underlying forces (e.g. population growth) are the root causes or fundamental factors behind the proximate sources. Proximate factors operate more at local scales, whereas underlying forces can operate at scales ranging from national to global (Turner et al., 1993). Attention is more often focused on proximate causes of biodiversity loss (e.g. Sodhi et al., 2004), but conservation actions that consider or address only proximate causes or single drivers of biodiversity loss are unlikely to be effective because most often drivers acts synergistically in threatening biodiversity.

Of the various processes leading to biodiversity loss, the most notorious is habitat destruction (Primm and Raven, 2000), an environmental process that renders habitats unsuitable to support species. Considering that tropical forests are the key habitats, habitat loss due to deforestation is a major deriver of biodiversity loss in the region. However, before discussing the key driving factors vis-à-vis their impacts on biodiversity in Southeast Asia (Sections 3 and 4), we first highlight the inextricable linkage between deforestation and habitat loss.

Currently, the proportion of land area occupied by forests in the region varies from 3 percent for Singapore to 70 percent for Laos, but the annual regional rate of deforestation (1.3 percent) is among the highest in the world (Table 1). In most Southeast Asian countries, forest area change has been negative despite implementation of afforestation and reforestation projects. For example, Thailand's forest resources including evergreen montane rainforests were markedly reduced between the 1960s and 1980s by conversion to agriculture, land resettlement, and dam and road construction. Indonesia also experienced high rate of deforestation between 1990 and 2005. In fact, after Brazil, Indonesia suffered the next largest annual forest loss between 2000 and 2005 at a rate of -1871 thousand ha/year (FAO, 2005). This gives some support to predictions that in the absence of appropriate intervening policies, by 2100, a quarter of biodiversity in Southeast Asia may be wiped out by deforestation (Sodhi and Brook, 2006).

Figure 3: Driving forces and processes of biodiversity loss in Southeast Asia



Apart from its impact on biodiversity, deforestation can directly affect human wellbeing. Indeed, forest ecosystems provide important goods and services for human livelihoods and environmental health. Such goods and services include water, energy, landslide protection, agricultural/forest products and genetic material. At the same time forests are important biological reserves that can detect and modulate regional climate change patterns as well as moderate the occurrence of infectious diseases (Beniston, 2003 in IPCC, 2007; and Foley and Asner et al., 2007). Forest ecosystems also store terrestrial carbon in biomass and soils interacting in the carbon cycle between air and land. Additionally, depending on the integrity of natural forests and how they are managed they can be a source of atmospheric carbon. The carbon density of Southeast Asian forest can be up to 500 Mg/ha logging but conversion to agricultural land can reduce the carbon density to less than 40 Mg/ha (Lasco, 2002).

Box 2: Linking forestry, agriculture, mining with deforestation in the Philippines.

Historically, deforestation in the Philippines has been driven by commercial and community logging. Slash and burn agriculture and forest land conversion are also major proximate causes of forest cover loss (Kummer, undated).

Logging between 1969 and 1998 was at 2,000km^2 annually (CI, 2009). Illegal logging is still occurring in several provinces though logging and any commercial exploitation of old growth forests were banned in 1992 under the National Integrated Protected Areas Act. Even though the forestry sector has such a large impact on biodiversity and landscapes, in 2006 the forestry sector in Southeast Asia had only 0.4% of the total labour force whereas in the Philippines it captures 0.1% of the labour force with contributions of USD 560 million to the economy (FAO, 2009). There has been high export demand placed on timber, by importing countries such as Japan. In a critical analysis of the state of deforestation in Malaysia, Philippines and Indonesia, Dauvergne (1997) identifies the major drivers of forest loss as domestic forest policies aided by subsidies and loans and lack of political will to address deforestation and the associated environmental problems coupled with foreign aid, import tariff incentives from buyer countries and usurious private rent-seekers both from inside the country and abroad.

In the 1600s, old growth forest that covered over 90% of the Philippines decreased to 7 percent by 1997, a decline considered as the most rapid and severe in the world (Heaney et. al., 1998). Forests in the Philippines are threatened by population pressure with a population density of 1000 persons to 83 hectares of forests in 2005 (FAO, 2009). The country also has a large rural population heavily dependent on natural resources and agriculture. In the Cordellia regions, 92 percent of the 1.3 million are indigenous peoples predominantly dependent on agriculture. In this region open pit mining and upper mossy forest conversion to small scale agricultural plots and lower elevation large-scale agriculture and overlapping land uses have tremendous impact on ecosystem services of the mountainous region and management of protected areas (Ga-ab, 2008). Mining activities are also an imminent threat to the Philippines forests. Mineral resources are found often in areas rich in biodiversity, populated by indigenous peoples. In 1997, mining activities covered more than half of the remaining forests (CI, 2009).

Forest degradation has resulted in increasing frequency and intensity of floods and droughts, erosion, landslides, siltation of coral reefs and decreased groundwater supplies (Heaney et. al., 1998). In 1993, 1995, and in 1997 the number of floods occurring in the Philippines were 26, 34, 38 respectively (ADB, undated). In mid-December of 2003, a series of landslides occurred in the Philippines province of Southern Leyte as hillside soils became saturated (NASA, 2003). These events can be linked to deforestation.

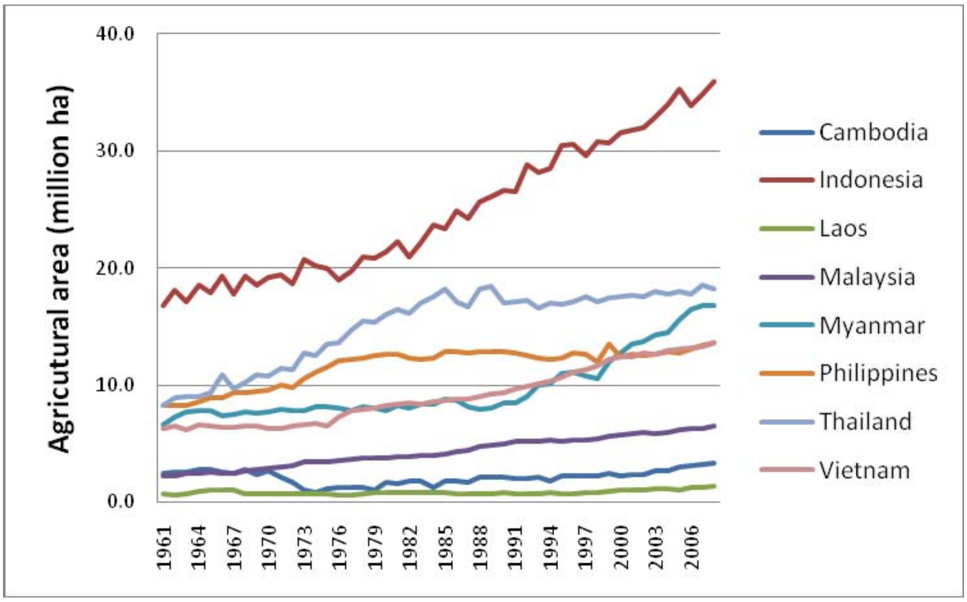
3. Human Related Drivers of Biodiversity Decline
3.1 Agriculture

3.1.1 Agricultural Expansion

Agriculture contributes significantly to the GDP of most countries in the region, for example 33% of GDP in Cambodia and 11.4% in Thailand (FAO, 2006). Agricultural labour has been decreasing simultaneously with a decrease in rural populations in the region, for example, in Malaysia it decreased from 41% in 1979 to 16% in 2004 (FAOSTAT, 2006). Even so, several countries still have large rural populations largely dependent on agriculture (Zhai and Zhuang, 2009). Cambodia's rural population remained relatively high moving from 88% in 1979 to 81% of total population in 2004 (FAO, 2006).

At the same time the production and trade of agricultural commodities has increased significantly throughout the region since the 1960s. With the exception of Cambodia and the Philippines, all other countries have more than doubled their cultivated area (see Figure 4). This agricultural expansion is mainly at the expense of natural ecosystems and particularly primary forests.

Figure 4: Agricultural land use in S.E. Asia



Data Source (FAO, 2010)

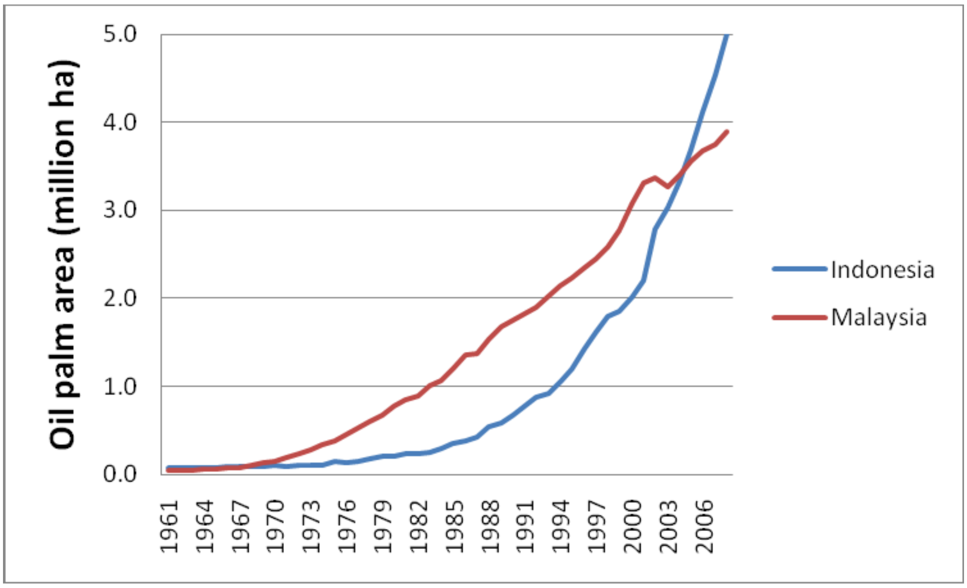
Even though this agricultural expansion is to be expected in a region that faces some of the highest incidences of malnutrition globally, it is interesting to note that the expansion happened simultaneously with an increase in the trade of agricultural commodities (see section 3.4). An interesting example is the case of oil palm cultivation in Indonesia and Malaysia[5]. Estimates indicate that both countries have increased their cultivated land area by 113.1% and 189.2% respectively between 1961 and 2007 (FAO, 2010) with a significant fraction of this agricultural expansion being

[5] Palm oil is the most produced and traded vegetable oil globally (FAO, 2010). As a result it has traditionally been an important part of the diet in several areas of the world. However, significant amount of palm oil is now used for the production of transport fuel (i.e. biodiesel), refer to Section 3.3.

the result of oil palm expansion. As of 2008 oil palm plantations, constituted 13.9% and 60.2% of the total agricultural land in Indonesia and Malaysia, respectively (refer to Fig. 5). As a result, Indonesia and Malaysia have become the major oil palm exporters capturing more than 90% of the global market. In fact, Malaysia appears to have shifted its focus from rubber to palm oil exports in order to capitalize on the multiple demand of oil palm for food and energy (biofuel). However, this agricultural expansion did not come without any adverse environmental effects.

Agriculture, extensive monoculture in particular, is a significant driver of biodiversity decline (MA, 2005). Sodhi et al. (2004) suggest that conversion of primary forest for agricultural uses has a particularly detrimental impact on biodiversity given the combined effects of habitat loss/fragmentation and the subsequent depletion of nutrients from the soils. Oil palm plantations are particularly hostile to biodiversity and are major agents of deforestation and other drivers of biodiversity loss (see Section 3.3 for more details).

Figure 5: Oil palm expansion in Indonesia and Malaysia.



3.1.2 Land Management and Tenure Systems

Disturbed lands broadly refer to any land that includes secondary, fragmented and selectively logged forests. Swidden lands can also be categorized as disturbed lands as swidden agriculture involves "cutting living vegetation in the dry season, letting it dry, burning it late in the dry season and then planting a crop in the ashes early in the wet season" (Fox and Volger, 2005). Swidden cultivation has been the predominant method of cultivation in Southeast Asia for centuries. Although it still comprises 25-33% of land use in the region, swidden cultivation has progressively decreased, giving way to settled and commercial cultivation of crops such as paddy, tree crops and oil palm, rubber and timber plantations. Swidden lands also go through a cyclical process of cultivation, fallow and secondary growth. Secondary growth in these tropical regions has been observed to be species diverse and useful to sequester carbon (Padoch et al., 2007).

Swiddeners consciously cultivate a diverse set of landraces and varieties of a crop adapted to local conditions, which are increasingly lost during the process of commercialization. For example, in Vietnam, currently only five genetically engineered varieties of rice are cultivated on a large scale versus 20 traditional varieties cultivated earlier (that is, the number of varieties of rice in common cultivation) (Cassellini, 2001). Similar reports from Thailand indicate that there has been a decrease in the number of rice germplasm collections in the country, as farmers have taken to planting new varieties and paddy fields are giving way to urban development. This is the case of several indigenous varieties, which have been lost due to loss of natural habitats (Thailand Third National Report on the Implementation of the Convention on Biodiversity, 2006). The reduction in swidden cultivation is also a result of government policies to promote nature preserves, other development projects and encourage commercial cultivation of cash crops and plantations.

While some researchers call for a revisit of policies towards swidden farming, it is also noteworthy that the extent of this practice has not been properly documented and such land use is usually classified as 'other' types of forest/ degraded forests/ secondary growth, thereby obstructing efforts to monitor benefits from such land use practices. Community-led environmental governance is being increasingly recognized and mainstreamed into forest conservation policies such as Community Forest Programs. Such initiatives have led to a significant increase in forest regeneration and an improvement in diversity (Ravindranath et al., 2006). Most recently the direct impact of rural peoples on tropical forests appears to have stabilized and could even be diminishing in some areas (Butler and Laurence, 2008).

Other cultivation practices harmful to biodiversity include drainage, fertilizer run-off from the plantations and the use of agrochemicals (refer to Section 4.2). For example, approximately 25 different pesticides are deployed in oil palm plantations in Indonesia, which are not monitored as they are not controlled or documented (Down to Earth, 2005) Owing to government subsides on pesticides and farm chemicals in Vietnam, pesticide applications by farmers on field crops and orchards exceeded the permissible limits by 2 – 45 times, leading to increased pest resistance along with other ecological impacts.

Land tenure is highly diversified in Southeast Asia. A recent study of land tenure systems in the region indicates that neither state nor private/customary land allocation guarantees tenure security (Table 6). Land tenure problems in the region relate to fragmented policy frameworks that result in multiple laws and regulations that weaken the negotiating positions of landholders, increase land disputes, complicate co-ordination between different government departments concerned with land administration, and hinder adequate land financing opportunities (Guo, 2007). In countries such as Vietnam where liberalization of allowed a free market whilst the state retain formal ownership, there has been a sharp increase in rural landlessness amongst the poor and the non-poor (Ravallion and van de Walle, 2008). The impact of the landless or "shifted cultivators" on biodiversity has long been recognized in the literature (e.g. Myers, 1985). Due to lack of alternative, the landless shifts to available unoccupied public land – usually forests. The lack of tenure security in the new found land also implies lack of incentive to invest in environment-conserving technology. Clearly, these are challenges that need to be overcome, within the political realities of a country, to ensure better land management and developing pragmatic land tenure systems is seen as an essential driver to this effect, whether they be in terms of clear title deeds, or clear terms of usufructory rights between different stakeholders.

In recent times, most governments in Southeast Asia have reworked tenure systems in forest areas and have reclassified previously community-held and managed lands as nature preserves belonging to the State. It is noteworthy that the degree of removal of non-wood forest products is very low in countries where state ownership is complete. Conversely, in Vietnam, where state control is mixed with private and other forms of control over forests, the forests continue to be accessed for non-wood requirements including food, medicine and cultural purposes (FAO, 2005). Relocation of people from their native areas to new locations has triggered degradation in the new areas as they were observed to be less caring of their new environments than their culturally linked lands (Cassellini, 2001), apart from the population pressure on limited spaces in the new areas (Fox and Volger, 2005).

Table 6: Classification of land tenure systems based on land allocation and tenure security

	Greater role of private or customary allocation	Greater role of state land allocation	Greater security of tenure	Less security of tenure
Thailand	√		√	
Vietnam		√	√	
Laos		√		√
Cambodia		√		√
Philippines	√			√
Indonesia	√			√

Modified from Guo (2007)

It is understandable that different countries have different approaches to secure land tenure systems for different stakeholders, it is imperative that the policies are pragmatic within the socio-political contexts, to allow conflict free use and management of lands for different production purposes. While in some cases, clear title deeds have been found effective, in some other cases as in Thailand, use of customary allocation of land and resources have been found effective. In either case, the terms of ownership and use are clear that allows decision making with minimal externalities.

3.1.3 Agriculture as a driver of climate change

Agricultural activities are significant emitters of global greenhouse gases (GHGs) and as such agricultural activity is a major driver of anthropogenic climate change. Emissions from agricultural sources are 14% of global GHG emissions in 2000 with developing countries accounting for three quarters of agriculture emissions in the case of rice (WRI, 2006; Stern Review). Climate change has been identified as a potentially significant threat to biodiversity in the region (refer to Section 4).

As forests are cleared in the region for agricultural purposes, crop residues are burnt, agriculture is intensified (e.g. through mechanization and increased fertilizer/agrochemical use) and livestock are raised, large quantities of GHGs such as CO_2, CH_4 and N_2O are emitted. Rice paddies, which have been increasing in productivity across Southeast Asia, are important emitters of CH_4 (IPCC, 2000). Apart from those primary agricultural activities, the associated land-use change also contributes significantly to CO_2 emissions (IPCC, 2007). This additional contribution from land-use conversion seems to further unbalance the annual net flow of CO_2 between agricultural lands and the atmosphere. Not only are these emissions contributing to enhanced greenhouse effect, they also represent a loss of useful carbon and nitrogen which are potential energy sources for crop and plant production.

3.2 Biofuel Expansion

First generation biofuels[6] currently constitute one of the most controversial energy sources. Despite initially being heralded as environmentally friendly energy options there is currently significant evidence about their negative impact on the environment (e.g. SCOPE, 2009), biodiversity (Fitzherbert et al., 2008) and the climate (Fargione et al., 2008). Several countries in Southeast Asia are currently increasing their biofuel production capacity. The main factors behind this boost in biofuel production include energy security, climate mitigation and socioeconomic issues such as rural development, poverty alleviation, increased employment and foreign exchange savings (Yan and Lin, 2009).

The major biofuel producers in the region are Indonesia, Malaysia, Thailand, the Philippines and China. According to Zhou and Thomson (2009), the adoption and proliferation of biofuel policies in the region are a result of energy security concerns and other socioeconomic issues (refer to Table 7). On the other hand, environmental considerations do not seem to have influenced significantly the production of biofuels given that these countries are not required to reduce their GHG emissions under the prevailing United Nations Framework Convention on Climate Change (UNFCCC) agreements.

Currently both biodiesel and bioethanol are pursued as alternative transport fuel options in the region but the availability of biofuel feedstocks is the main limiting factor for their production (refer to Table 8).

Table 7: The main determinants of biofuel production in Southeast Asia

	Security	**Economy**			**Social**		**Environment**	
	Energy security	Trade balance	Price of petroleum	Economic development	Increase agricultural employment	Rural development	Climate change	Air pollution
China	√	√			√	√		√
Malaysia		√	√	√			√	
Indonesia	√			√	√	√		
Philippines	√	√		√				√
Thailand	√	√		√	√	√		

Source: (Zhou and Thomson, 2009)

[6] e.g. bioethanol from food crops (sugarcane, corn, cassava etc) and biodiesel from oil seeds (e.g. from oil palm, soybeans etc).

Table 8: Biofuels and feedstocks for the main Southeast Asia producing nations

	Main option	Feedstock	Secondary option	Feedstock	Comments
China	bioethanol	Corn (mainly) and wheat (secondarily)	Biodiesel	Animal fats and waste vegetable oil	Cassava and sweet sorghum are used for bioethanol in an experimental basis. Assess the potential of rapeseed, Jatropha, sunflower seeds, sesame seeds and several types of beans and nuts for biodiesel production.
Malaysia	Biodiesel	Palm oil			
Indonesia	Biodiesel	Palm oil (mainly), Jatropha (secondarily)	Bioethanol	Cassava and sugarcane	
Philippines	Bioethanol and biodiesel	Sugarcane (for bioethanol) and coconut oil (for biodiesel)			Research and development is conducted in order to assess the feasibility of using Jatropha for biodiesel and cassava for bioethanol
Thailand	Bioethanol	Sugarcane and cassava	Biodiesel	Palm oil and Jatropha	

Source: (Zhou and Thomson, 2009)

Oil palm is the major feedstock cultivated in the region, particularly in Malaysia and Indonesia, for biofuel production purposes. Currently these two countries account for more than 90% of world production while both countries are significant exporters of this commodity (FAO, 2010)[7]. Concurrently, these two countries contain a significant portion of the planet's remaining tropical forests, which harbor several endangered species - indeed, Sundaland and Wallacea, two of the world's twenty-five biodiversity hotspots (Figure 2). It is feared that the oil palm expansion spurred by biofuel production within the two countries and for feedstock exports can have significant impacts on biodiversity. In fact large scale oil palm cultivation can influence directly and indirectly three key drivers/processes of biodiversity loss, namely habitat destruction, pollution and climate change.

Koh and Wilcove (2008) suggest that palm oil plantations in Malaysia and Indonesia have replaced to a great extent primary and secondary tropical forests and to a lesser extent pre-existing cropland. According to their calculations, 55-59% of oil palm expansion in Malaysia and at least 56% in Indonesia occurred at the expense of primary forests. Fitzherbert et al., 2008 estimate that between 1990 and 2005, oil palm expansion resulted to a net loss of 1 million hectares and 1.7 to 3 million hectares of forest in Malaysia and Indonesia respectively. The overall impact on biodiversity could be quite substantial.

[7] Note here that energy security and environmental concerns (i.e. climate change mitigation) in developing nations might be responsible for the phenomenal oil palm cultivation expansion in Southeast Asia. Indeed the EU is a major importer of palm oil from the S.E. Asia with an increasing quantity of this palm oil used for biodiesel production purposes. Both energy security and climate change concerns are high in the agenda of the European Commission with significant policies being adopted (most notably Directive 2009/28/EC).

Oil palm plantations harbor fewer species of birds (Peh et al., 2005) and butterflies (Hammer et al., 2003; Dumbrell and Hill, 2005) than primary forest, logged forest and rubber plantations (Fitzherbert et al., 2008; Danielsen et al., 2009). In fact, in most cases the majority of forest species was lost after the conversion to oil palm plantations and was replaced by smaller numbers of non-forest species, mainly generalist species of low conservation value (Danielsen et al., 2009). The loss of biodiversity in oil palm plantations is due to the fact that such habitats are structurally less complex than primary forests, have a shorter life time and are major landscape fragmentation factors (Fitzherbert et al., 2008; Danielsen et al., 2009).

Oil palms, like all other plants, emit Volatile Organic Compounds (VOCs). There are concerns that oil palm expansion might result in greater VOC emissions (Royal Society, 2008; Hewitt et al., 2009). In fact, Hewitt et al. (2009) have shown that VOC and nitrogen oxides (NOx) emissions[8] are greater from oil palm plantations than from surrounding primary rainforest. Additionally, land that is appropriated for oil palm cultivation is sometimes cleared through the use of fire (e.g. van der Werf et al., 2008), also refer to Section 4.1. Biomass burning has been identified as a major source of atmospheric pollution affecting significantly biogeochemical cycles (Bytnerowicz et al., 2008; Crutzen and Andreae, 1990).

The palm oil industry has been in the past a major source of pollution in Malaysia (Muyibi, et al., 2008). Palm oil mill effluent (POME) is characterized by high levels of Biochemical Oxygen Demand (BOD). At the same time palm plantations consume large amounts of fertilizers – the largest amount of fertilizers than any other crop in Malaysia (FAO, 2004; FIAM, 2009), while they are the third highest consumer of fertilizers in Indonesia (FAO, 2005). High BOD and nutrient runoff from fertilizer application have been associated with severe environmental problems such as eutrophication and hypoxia and as a result can significantly affect aquatic biodiversity.

Life Cycle Assessment (LCA) studies have shown that biodiesel from palm oil has generally lower GHG emissions than conventional fossil fuels (e.g. Zah et al., 2007; RFA, 2008). However in some cases these studies do not take into consideration the GHG emitted as a result of direct and indirect land-use change. Oil palm plantations are expected to be net carbon sinks only if they are established in crop/grassland and not on forested areas (Danielsen *et al*., 2009). Depending on the forest clearing method used, it would take 75-93 years[9] for an oil palm plantation to compensate the carbon lost during the loss of the initial forest and 692 years if that happens on peatland. On the other hand, if the oil palm is cultivated on grassland it would take just 10 years to compensate for the carbon lost during land-use change. Similar findings have been reported in the literature (e.g. Fargione et al., 2008; Germer and Sauerborn, 2008; Gibbs et al., 2008), leading to the conclusion that oil palm biodiesel might in fact produce greater amounts of GHGs than conventional fossil fuels if direct and indirect land use impacts are considered.

3.3 Trade

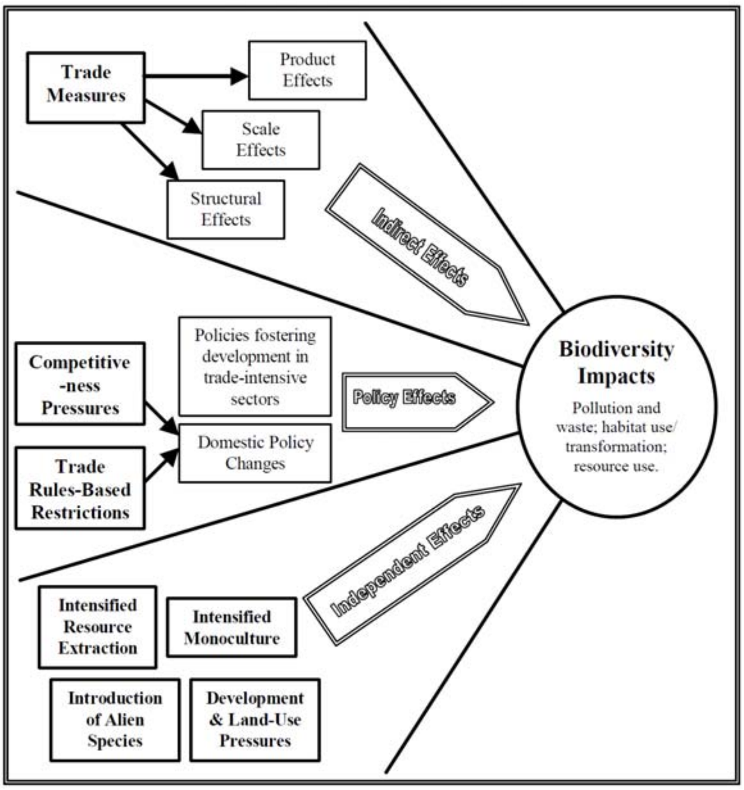
[8] VOCs and NOx are tropospheric ozone precursors (O_3) which is both a potent GHG and can affect animals and plants.

[9] The higher estimate corresponds to when fire use as a land clearing method.

Trade in agricultural commodities and endangered species have been two major underlying and interlinked drivers of biodiversity loss in S.E. Asia (Schipper et al., 2008). In fact agricultural activities constitute one of the most important causes of biodiversity loss globally (e.g. MA, 2005) given that agriculture is a major driver of habitat loss and fragmentation as discussed in the previous sections. On the other hand trade can be directly linked with other direct drivers of biodiversity loss such as species overexploitation and introduction of species.

Despite the almost universal understanding that increased consumption and trade activities can negatively affect biodiversity, the mechanisms through which this happens are difficult to delineate. According to Conway (1998) trade can have indirect, policy and independent effects on biodiversity as summarized in Figure 6. The independent effects are the most straightforward to assess and have therefore received the greatest attention from academics and practitioners.

Figure 6: Effects of trade on biodiversity



Source: Modified from Conway, 1998

Conway (1998) suggests that there is significant evidence indicating that trade liberalization in Indonesia has affected biodiversity through:

- product effects (e.g. rattan, wildlife trade);
- structural effects (e.g. fisheries, mining);
- intensified extraction of natural resources for export (e.g. shrimps, frogs);
- intensification of monoculture (e.g. oil palm);
- policies encouraging trade development in trade intensive sectors (e.g. forest products, agricultural products, oil and gas).

It is no wonder that there are different multi-lateral institutions and programmes to understand and regulate the trade of agricultural commodities and endangered species for the benefit of biodiversity. For example, between 2005 and 2009, the United Nations Environment Programme (UNEP) established an Initiative on Integrated Assessment of Trade-Related Policies and Biological Diversity in the Agriculture Sector. The primary goal of the initiative is to enhance capacity in developing countries to develop and implement policies that safeguard biological diversity whilst maximizing sustainable development gains from trade liberalization in the agriculture sector[10]. Perhaps the first major programme concerned with the linkage between biodiversity loss and trade is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)[11] that regulates the trade of threatened and endangered animals in order to assure their conservation. Currently there are approximately 900 species included in Appendix I (most threatened by trade) and about 33,000 species in Appendix II (not necessarily threatened with extinction but that may become so if trade is not controlled properly). Populations of a large number of these species are found in or are endemic to Southeast Asia.

In fact, wildlife trade is a booming business in the region conducted both through formal and informal networks (CITES, 2010). Many recent studies have shown that the presence of the main wild traded species has declined in their natural habitats. This indicates the loss of commercially valuable biodiversity in the region due to trade and overexploitation (World Bank, 2008). The Wildlife Trade Monitoring Network (TRAFFIC) has conducted studies on the trade of endangered species. Its reports have suggested that wildlife trade in Southeast Asia indeed poses a threat to regional biodiversity (refer to Box 3).

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[10] http://www.unep.ch/etb/areas/biodivAgriSector.php

[11] http://www.cites.org/

Box 3: Examples of illegal wildlife trade in S.E. Asia

There is very little evidence to suggest a significant decrease in the trade of gibbons and orangutans in Sumatra, Kalimantan, Java and Bali in the past 15 years. (Nijman, 2009; Nijman, 2005a, 2005b). Instead there is indication that *"…trade is still very much threatening the survival of these apes*" (Nijman, 2009: vii)

Both protected and non-protected species of cats are traded in Myanmar. However, those species, which are globally threatened, are offered in the country in significantly larger numbers than non-threatened species. *"…[T]his, and the frankness of the dealers, suggests a serious lack of enforcement effort to prevent this illegal trade, and highlights the threat that trade poses to already threatened species" (**Shepherd and Nijman**,* 2008a). The trade of tiger also continues openly in several areas of Sumatra. While tiger trade appears to be declining in some parts of the island, trade has increased in others (**Ng and Nemora**, 2008).

Thailand still has one of the largest and most active ivory industries seen anywhere in the world despite the fact that the quantity of worked ivory in Thailand seen openly for sale has decreased substantially in the past (Stiles, 2009a). Vietnam has experienced an increase in the number of artisans working ivory, which suggest that demand for ivory is rising (Stiles, 2009b). Finally, ivory and other elephant parts are routinely smuggled out of Myanmar, which indicates a serious lack of law enforcement and a blatant disregard for international conventions and national laws (**Shepherd and Nijman**, 2008b).

Reptile trade out of Indonesia is allowed only if the animals have been bred in captivity. Surveys suggest that for the majority of reptile species and for the majority of exporting companies, it does not appear that captive breeding of these species in commercial quantities actually occurs at these facilities. On the contrary, it appears that "wild-caught" animals are labeled as "bred in captivity" in order to allow their export (**Nijman and Shepherd**, 2009).

Even though in Indonesia the local use of the box turtle is minimal, its international trade is extensive and represents the major threat to the species' survival. The extent of plastrons and carapaces illegally traded is also of major concern (***Schoppe, 2009a****).* Similar findings were reported for Malaysia **(Schoppe, 2009b)**.

It should be noted that the Southeast Asia wildlife trade supplies local and global markets involving several actors such as rural harvesters, professional hunters, traders at several points along the supply chain as well as the final consumers (World Bank, 2008). Many of these species are exploited and traded in order to meet basic subsidence needs (i.e. food, medicine) and as a source of income. Furthermore the increased economic affluence across the region (e.g. in China) seems to be a much stronger driver of illegal wildlife trade in the region than poverty (ibid).

3.4 Urbanization

The Southeast Asian region has witnessed a tremendous increase in urbanization in the last few years. The proportion of urban population is expected to increase to about 50% in 2025 (Table1). The increase in urbanization reflects economic growth at the expense of biodiversity in the region. Urban expansion is concentrated primarily around urban cores, replacing peri-urban agriculture and natural vegetation at a slower rate than in developed countries of the world (McGranahan and Satterthwaite, 2003). This pattern of urban growth markedly homogenizes biota. Dense populations and industrial economic activities in the urban centers places tremendous pressure on natural habitats. A recent study indicates that 29 of the world's 825 ecoregions[12] have over one-third of their area urbanized, and these 29 ecoregions are the only home of 213 endemic terrestrial vertebrate species (McDonald et al., 2008). The same authors have shown that several important and highly biodiverse eco-regions in Southeast Asia were highly urbanized in 1995, e.g. Western Java rainforests (22.7% urbanized), eastern Java-Bali rainforests (18.2% urbanized), Indochina mangroves (15.3% urbanized), Western Java montane rain forests (10.2%) and peninsular Malaysia rainforests (10.1% urbanized) with urbanization trends expected to increase dramatically in the coming decades. Singapore with 100% urbanization is another example of the negative impact of urbanization on biodiversity. In the process of urbanization, the country lost between 34-87 % of butterflies, fish, bird and mammals forever (Sodhi et al., 2004).

Urban production and consumption activities are key urban processes that have been identified as particularly damaging to biodiversity (Puppim de Oliveira *et al*., 2010). The latter can be linked to the increase of transport and the global circulation of commodities. A telling example in the region is the case of Vietnam, toxic effluents, transport-related air pollution, heavy metals and hazardous waste enter the sewage system or are dumped in landfills, degrading freshwater, marine and soil systems (Casselini, 2001).

One way of estimating the level of risk posed by urbanization to biodiversity is to determine the distance between urban areas and protected areas (MacDonald et al., 2008). The shorter the distance between urban areas and protected areas, the higher the potential human impact on biodiversity. As at 1995, 50% of protected areas in Southeast Asia were within 57 km of cities. By 2030, this distance will shrink by 30% to 40 km (Table 9). Eighty-eight percent of protected areas that are likely to be impacted by new urban growth by 2030 are in countries of low to moderate income with limited institutional capacity to adapt to anthropogenic stresses on biodiversity (McDonald et al., 2008). This phenomenon calls for strategies to protect biodiversity from future urban expansion.

[12] Ecoregions are delineated areas of relatively homogeneous environmental conditions and species composition used for conservation priority-setting.

Table 9: Distance from protected areas (km) to the nearest city with 50,000 inhabitants or more in Asia

	1995			2030		
	First Quartile	Median	Third Quartile	First Quartile	Median	Third Quartile
East Asia	18	43	84	10	23	45
Southcentral Asia	19	38	80	13	28	58
Southeast Asia	27	57	94	20	40	74
Western Asia	7	26	57	4	21	48

(Adapted from McDonald et al., 2008)

4. Climatic Impacts and Biodiversity Loss

Climate change has direct and indirect impacts on biodiversity. The direct effects are through changes in temperature and precipitation that affect individual organisms, populations, species distribution, and ecosystem compositions and functions. Global warming is projected to increase the risk of extinction for already vulnerable species with limited climatic ranges and restricted habitats (IPCC, 2002)[13]. The indirect effects of climate change are through climate altering the intensity and frequency of perturbations such as forest fires. Changes in the frequency and intensity of perturbations affect whether, how and at what rates existing ecosystems will be replaced by new species (IPCC, 2002). Climatic factors typically amplify the effects of anthropogenically-driven processes mentioned in the previous section in accentuating biodiversity loss.

4.1 Climate Change and Fires

Forest fires are emerging as one of the key threats to tropical forests. Forest fires release 20-25% of annual global carbon dioxide emissions (Moutinho and Schwartzman, 2005). The El Nino effect has been identified as a key factor that combined with other land management practices to increase the devastation of the fires in Indonesia (Sodhi et al., 2006). The experience of the 1997/98 ENSO particularly demonstrates how the effects of climate change and land use can synergize to threaten biodiversity and ecosystem services. Drought conditions triggered by ENSO across Southeast Asia markedly increased tree mortality and flammability (Gullison et al., 2007). Secondary forests were the most affected in the 1997-1998 fires in Southeast Asia (Murdiyarso et al., 2002) with up to 5 million hectares and 4.6% of canopy trees in Indonesia affected (Sodhi et al., 2006; Schweithelm, 1998). Other estimates indicate that in 1997-1998, 2002 and 2005, fires in Southeast Asia destroyed more than three out of the 24 million hectares of peatlands (representing 60% of the world's tropical peatlands). In addition to loss of habitats, it is estimated that 1000 orangutans in Indonesia (2.5% of the population) died from the 1997-1998 fires and it is predicted that future fires may kill

[13] It should be noted that climate change might not be a significant driver of biodiversity loss in the tropics (Sodhi *et al*., 2004). However, the poor understanding of the links between climate change and biodiversity loss in Southeast Asia as well the high uncertainties associated with its assessment have been highlighted in the academic literature (Sodhi *et al*., 2004). Nevertheless there is evidence to suggest that very biodiverse ecosystems in the tropics, particularly montane areas can be severely affected by climate change (Sala *et al*., 2000).

up to 3.5% of the orangutan population per event (Singleton et al., 2004; and Suhud and Saleh, 2007).

Forests that have experienced widespread or edge fires become more susceptible to further fires and adaptive species as their edges are drier and become more fragmented by previous fire occurrence (Nepstad et al., 2001). Increasing frequency and intensity of dry periods synergize with forest degradation and land clearing and amplifies the devastating effects of forest fires (Corlett, 2003).

Forest incineration releases carbon dioxide into the atmosphere joining the feedback loop between forests and atmospheric carbon (Strand, 2007). The Southeast Asian forest fires of 1997-1988 released up to 1.2 billion tons of carbon.[14] The regional smoke haze caused by the forest fires in southeast Asia in 1980s and 1990s received much attention due to their impact on regional climate change and regional air pollution and the effects on ecosystems, species, human health and the economy. Brunei Darussalam, Indonesia, Malaysia, and Singapore were seriously affected for several months by the forest fires of 1997-1998. The governments of the region began a joint effort to monitor, prevent and mitigate such hazards by establishing the ASEAN Agreement on Transboundary Haze Pollution (or ASEAN Haze Agreement) in November 2003. Potential hotspots are regularly identified for each country and compiled and published through the ASEAN Haze Watch. Not only are there concerns for air quality as it pertains to human health but studies have also looked at the impacts on rainwater acidity and effects on ecosystems. However, an analysis of rainwater in Brunei Darussalam during severe haze episodes in Borneo in 1994, 1997, and 1998 failed to reveal any significant impacts on rainwater acidity or wet deposition of hydrogen ions (Radojevic and Tan, 2000).

3.2 Climate Change and Species Distribution

Current global changes in climate have aroused interest in assessing the sensitivity of native species to climate change and the implication for biodiversity conservation. In addition to its interactions with existing fire regimes and air pollution, changes in climate affect ecosystems by shifting species ranges, composition and migration patterns; altering wildlife habitat, landscapes and succession patterns; and interacting with insect pests and pathogens (Blate et al., 2009; IPCC, 2000). IPCC 2007 reports that up to 30% of species are at increasing risk of extinction and approximately 15%-40% of ecosystems are being affected by climate change. In Southeast Asia there has been a general increase of 0.1 degree C to 0.3 degree C increase in temperature between 1951 and 2000 with a general decline in the number of rainy days, whereas in the Philippine the annual mean rainfall has increased since the 1980s. There is some variability in rainfall patterns within countries, such as Indonesia with increased rainfall in the northern regions and a decreasing rainfall in the southern region (IPCC, 2007). Global warming potentially causes species to move to higher elevations in search of more suitable habitat. In an analysis of the elevational distribution of Southeast Asian birds from 1971- 1999, Peh (2007) observed an upward shift of lower and upper boundaries for 94 common resident species in response to global warming. The upward shift occurred irrespective of habitat specificity, implying that climate change is an additional factor to anthropogenically-induced habitat destruction and biodiversity decline in Southeast Asia.

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[14] Information on ASEAN Secreatariat Webpage [http://www.aseansec.org]. Further information on ASEAN haze can be found at [http://haze.asean.org/].

The orangutan habitat in Indonesia has been influenced by the synergy of climate, rainfall and other factors. The El Nino event of 1997-1998 with increased hot, dry and drought weather affected the phenology including pollen patterns of trees in areas such as the Kayan Metarang National Park. This led to a decrease in the food supply as fruit productivity fell during 1998-1999-2000 resulting in the migration of orangutans to other areas. The fall in fruit productivity also affected other animals. It is predicted that climate change (in concert with other factors of human induced habitat loss, hunting and trades) will continue to challenge orangutan conservation in Indonesia (Suhud and Saleh, 2007).

Species extinction as a result of climate change is also a possibility as local factors such as land-use change, increased atmospheric carbon dioxide, and invasive species interact with global warming (Pounds and Puschendorf, 2004). Thomas et al., 2004 in a sample of 1,103 land plants and animals in terrestrial regions from Mexico to Australia suggest that 15-37% of species would become extinct by 2050 because of climate change, whereas other studies suggest a narrower range of species extinction of 20-30% if there is greater than 1.5-2.5 °C in the global average temperature (IPCC, 2007). Kitayama (1996) reported that water stress occasioned by the El Nino of 1991-1992 resulted in morphological adaptations in plants in montane environments.

Pine forests in Southeast Asia are affected by fuel wood collection; unsustainable resin tapping and deforestation has also decreased their area. In concert with these factors, the additional climate change threatens their growth and distribution. In a study of the impact of climate change on the distribution of two pine species (*Pinus kesiya* and *P. merkusui*), van Zonneveld *et al.,* (2009) found that only few areas in mainland Southeast Asia will be suitable for the species as a result of climate change in 2050. In the Malay Archipelago, climate change may favour *P. mekusii* plantations. However, temperatures in the forests in eastern Thailand and northern Cambodia are expected to increase beyond the tolerance range of these species therefore threatening these species in combination with other factors such as diseases and insect pests whose virulence may also be triggered by climatic factors. A combination of the human induced stresses – forest burning, fragmentation and degradation – and other climate-driven factors such as outbreaks of insects and pests, drought and heat may lead to forest dieback. Allen (2009) in a global review lists several examples of drought related mortalities including Dipterocarpaceae in tropical moist forests in Borneo, Malaysia (Allen, 2009).

4. Policy Responses and Conclusion

Clearly, several of the stress factors affecting biodiversity loss are anthropogenic in nature. These pressures relate directly to policy directions undertaken at the national level. The policies, while serving to fulfill a few objectives, such as increase in GDP or conservation of forests, have had undesirable impacts on the biodiversity and welfare of the people immediately dependent on such resources for their livelihoods. Of greater import is the fact that the vulnerability of the several countries in the region due to climate change is high, their adaptive capacities as can be evidenced from socio-economic factors, technological and infrastructural development are not at par (Yusuf and Francisco, 2009)[15]. Broadly, policy responses have been designed on the following categories:

- **Monitoring and regulation**

Loss of biological resources through trade and other flows from the regions has been well acknowledged. The trade of wildlife has been targeted by important multi-lateral environmental agreements such as CITES. However the multi-faceted nature of the issue and the number of stakeholders involved both from the supply and the demand sides of the trade chain make the enforcement of such mechanisms difficult. For S.E. Asia there is a general lack of knowledge concerning the nature, causality and interlinkages of the trade of endangered species (World Bank, 2008). The World Bank and TRAFFIC have identified key areas and laid down a number of different interventions in order to minimize illegal trade of endangered species and as a result the risk it poses on biodiversity in the region. These range from improved monitoring mechanisms, inclusion of wildlife trade concerns in planning of infrastructure development, targeting interventions towards powerful groups in the trade chain, building multi-agency and cross jurisdictional law enforcement capacity and multi-lateral enforcement in the region, and have a balanced mix between positive incentives (for prevention) and penalties (World Bank, 2008: 68-74).

Similarly, periodic assessments of the impacts of climate change mitigation on biodiversity are necessary. There is a need to develop strategies for optimizing biodiversity conservation and ecosystem services management (Chan *et al*., 2007). The IPCC has proven effective at providing the leading scientific review of climate change through corporative global efforts. Likewise the proposed Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services can provide the international science-policy interface that is needed for biodiversity[16]. That could enable a scientific framework for tackling changes to biodiversity and aligning conservation priorities with ecosystem services.

- **Land use strategies**

The foregoing arguments in the report do imply the need for encouraging resilient and sustainable land use strategies in the region. Conversion of the tropical forests for oil palm plantations to meet growing biofuel demand has resulted in several natural and socio-political complications. Some suggestions to mitigate the impact while still making use of the opportunity arising from global demand include: shifting the production of biofuel crops to degraded/abandoned agricultural lands; adoption of improved and ecosystem friendly management practices; development of certification schemes with the involvement of multiple stakeholders (such as being developed by the Roundtable on Sustainable Palm Oil (RSPO);[17] and the creation of appropriate financial incentives to ensure sustainable production (Stromberg *et al*., 2010).

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[15] Yusuf, Arief Anshory and Herminia. A. Francisco, 2009, Climate Change Vulnerability Mapping for Southeast Asia, Economy and Environment Program for Southeast Asia, Singapore.

[16] IPBES [http://www.ipbes.net/]

[17] For more information refer (www.rspo.org)

Another area of concern is the increasing urbanization in the region. While this is considered a normal pattern in the cycle of development, it is important that some factors be considered in urban planning that aim to enhance ecosystem resilience. Such policy responses should include in addition to appropriate housing and transportation measures, innovative landscapes that integrate green spaces, urban agriculture and other functional habitats (Puppim de Oliveira *et al*., 2010).

- **Mitigation and adaptation responses**

Some innovative mechanisms that are being considered to enhance adaptive capacities of different countries in the region, in addition to reducing their vulnerability include: financial incentives through mechanisms such as UN-REDD, carbon markets, debt instruments and biodiversity compensation or offset schemes; payments for ecosystem services and funding for adoption of various measures related to reducing deforestation and degradation of natural ecosystems and/or to undertake additional measures to mitigate climate change (such as through Clean Development mechanisms); and, livelihood enhancement schemes that ensure income diversity and security to local communities and primary producers. The recent co-operation between Norway and Indonesia on activities to address greenhouse gas emissions from deforestation, degradation and peatland conversion is an interesting step in this direction. The project places an emphasis on participatory planning and livelihood guarantees in the process of achieving the objectives (Purnomo and Saloh, 2010)[18].

Policy makers need to realize that biodiversity conservation is not an automatic co-benefit of REDD. If REDD mechanisms only emphasize reducing deforestation rates, then market forces will most likely focus on areas that are cheapest to protect with the implication that biodiversity hotspot areas will not be cost-competitive (Grainger et al., 2009). Secondly, REDD emphasizes forests with high carbon density. Though there is considerable overlap of global carbon storage and biodiversity in terrestrial ecosystems, the synergies between carbon stocks and species richness are unevenly distributed (Strassburg et al., 2010). Besides, not all biodiversity hotspots are forests. This means that some high-biodiversity regions, would not benefit from carbon-focused conservation, and could become under increased pressure if REDD is implemented (Myers et al., 2000). Thirdly, deforestation processes that are not effectively halted by REDD may be displaced to other areas within or outside a country (Gan and McCarl, 2007). Nevertheless in all likelihood REDD plus will deliver some biodiversity benefits with measures to further incorporate rules to conserve biodiversity in all REDD projects, whilst private conservation funding that would not otherwise be eligible for REDD funding could be redirected and focused on forests of high biodiversity value. Appropriate monitoring and reporting of sub-national and transnational leakages should be a top priority. As highlighted elsewhere, livelihoods and practices of several indigenous and local communities are dependent on these biodiversity rich ecosystems, requiring careful analysis of the implications of such projects to their wellbeing.

[18] Purnomo, Agus and Yani Saloh, 2010. New approach could be elixir for Indonesia's deforestation malaise, Jakarta Globe, June 3 2010, from (http://www.thejakartaglobe.com/opinion/new-approach-could-be-elixir-for-indonesias-deforestation-malaise/378593) Accessed 18 June, 2010.

- **Research and Information, Education**

Addressing the impacts of climate change in this region requires both mitigation and adaptation responses with strong links between scientists and natural resources managers (Blate et al., 2009). Impact adaptation may include livelihoods diversification (decreased dependence on agriculture and forest resources) or change in management techniques (Rubio, 2007; Kaufmann, 1998). Blate *et al*. (2009), also lists several adaptation options for US forests some of which may be applicable to Southeast Asia. There is still a paucity of scientific information in Southeast Asia on the adaptive capacity of specific ecosystems to adapt to climate change. However, given the value of these ecosystems and agricultural systems to human development in Southeast Asia and the global significance of Southeast Asian forests it is important that policy makers and scientist accelerate both country and regional efforts to understand and adapt to the potential effects of climate change and anthropogenic land changes.

Collaborative research and responses between regional scientists, planners, policy makers and the private sector looking at simulating climate change with different scenarios, information sharing and mitigation and adaptation measures are essential (Tuan, 2009). There is also need for additional research on the links between climate change, biodiversity and economic development in the SEA region (ASEAN Centre for Biodiversity)[19]. Universities in Asia are increasingly sharing their successes and challenges in community empowerment and climate change adaptation research in an effort to strengthen the role of higher education in transferring and applying new knowledge to the challenges of society and local communities. Universities in Korea and Indonesia for example are further exploring programmes on climate change adaptation to increase the adaptive capacity of communities and practical education addressing the vulnerability of natural ecosystem (Tumiran, 2009; Lee, 2009). The University Network for Climate and Ecosystems Change Adaptation Research (UN-CECAR) is a promising initiative that can narrow the disparities between higher education institutions and academics across the region with respect to climate change adaptation research.

Several issues related to climate change are symptomatic of a greater malaise affecting ecosystems and resources that help regulate nutrient cycling processes. Recent literature, as seen in the foregoing, points to increasing concern and measures being taken to address the problem of their erosion and loss, especially in the hotspot regions of Southeast Asia. It is hoped that the momentum being generated would result in appropriate policy and economic measures based on appropriate scientific evidence and ground scenarios.

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[19] ASEAN Centre for Biodiversity [http://www.aseanbiodiversity.org]

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Chapter 2

Land Use and Carbon Sequestration

Dorothea S. Kimura

1 Influence of land-use change on Carbon Sequestration

1.1 General overview

Carbon (C) stock of an ecosystem highly depends on the land use and management factors. Usually continuous use of the land for a specific purpose leads to a stable condition of soil and aboveground plants (IPCC 2007). Thus, changing one land use to another may cause dramatic changes in the C stocks. In case of the tropical Asia forest cover change is a major driver of C stocks. During 1990 to 1997, the deforestation rate of humid tropical forest in Southeast Asia (0.91%) was the largest in the world. The annual loss of forest area was estimated as 2.5 G ha y^{-1}, which was almost the same as that of Latin America (Achard et al. 2002). ASEAN forest area declined from 234.7 million ha in 1990 to 211.4 in 2000 at an average rate of 1.0% (Phata et al. 2004). The Philippines and Myanmar have the highest rates of about 1.4% each, followed by Malaysia and Indonesia (about 1.2% each). Although forest area in ASEAN still remains considerably large, its growing stock has declined due to many reasons, including bombardment during the Vietnam War (in the case for Cambodia, Vietnam and Laos), and overexploitation, and illegal logging (Phata et al. 2004). The loss of forests in Cambodia has been relatively low (annual decrease of 0.6%), but growing stock has declined by about 284 million m^3 within 20 years during 1969–1986 (1.3% per year), continuing until recently due mainly to over-exploitation and illegal logging (Phata et al. 2004). In Thailand, over 60% of the primary tropical forests have been harvested between 1940 and 1990 (Dixon et al. 1994). Based on an average carbon stock in live vegetation in Asian tropical moist and seasonal forests of 200 Mg C ha^{-1} (Houghton and Hackler, 1995), it is estimated that about 465 Tg C were released every year between 1990 and 2000 from ASEAN additional to other carbon emissions from degraded forests due to overexploitation. Compared to the net carbon balance of tropical forests, this amounts to approximately 26% of net carbon release. At the global scale, where more regrowth occurs and the net source is smaller, the figure rises to about 29% (Phat et al. 2004).

1.2 C-stock in Southeast Asia

The change in C-stock can be evaluated by subtracting the C-stock before land-use change from that after the change. This means an evaluation of the C-stocks of a land-use type depends on the context and the types of comparisons made. A simple assumption of a fixed C-stock value for natural forest, secondary forest, perennial crops and annual crops suppose that the natural forest has the highest C-stock value of all other land-use types (Houghton 1999). For Asian tropical moist forest, C-stock in undisturbed vegetation and soil is estimated to be 250 and 120 Mg C ha^{-1}, respectively, while that of croplands is estimated to be 5 and 84 Mg C ha^{-1}, respectively. Conversion of natural forest to cropland leads to 66% loss of the C-stock. For Asian tropical seasonal forest, the C in undisturbed vegetation and soil is estimated to be 150 and 80 Mg C ha^{-1}, respectively, while that of croplands are estimated to be 5 and 56 Mg C ha^{-1}, respectively, leading also to a loss of 64% if the land cover is changed. Based on these numbers, Houghton (1999) calculated that tropical Asia contributed 54% of the annual net flux of carbon to the atmosphere due to land-use change.

These estimates do not consider site specific conditions. DeWalt and Chave (2004) found higher aboveground biomass in forest on nutrient-rich entisols than in forest on nutrient-poor oxisols. In contrast, van Schaik and Mirmanto (1985) reported lower biomass and faster turnover rates in forest on phosphorus (P)-rich soils across a chronosequence of volcanic terraces in northern Sumatra, and DeWalt and Chave (2004) reported similar Wndings in a regional comparison among four Neotropical sites on contrasting soils (Paoli et al. 2008). A study conducted in montane forest in Indonesia showed that fine root biomass decreased significantly from natural forest to the disturbed forests, and reached less than 60% of the fine root biomass value of natural forest in the agroforest systems. A similar decrease with increasing disturbance intensity was found for fine root necromass. Forest disturbance intensity had no significant influence on the vertical distribution of fine root biomass in the profiles. Factor analysis revealed that, fractional canopy cover was the most important factor influencing fine root biomass and fine root necromass, whereas diameter at breast height, stand basal area, stem density, soil pH and base saturation had only a minor or no influence on root mass. A reduction in canopy cover from 90% (natural forest) to 75% (disturbed forest) was associated with a reduction in fine root biomass by about 45% which indicates that timber extraction leads not only to canopy gaps but to corresponding 'root gaps' in the soil as well. Forest encroachment that is widespread in large parts of South-east Asia's remaining rainforests significantly reduces tree fine root biomass and associated carbon sequestration, even if it is conducted at moderate intensities only (Leuschner et al. 2006).

1.3 CO2 flux due to land-use change in Southeast Asia

The short term C flux is, however, much more complicated than the long term change in C stock. The carbon dioxide (CO_2) flux from tropical moist forest is the highest of all terrestrial ecosystems (Raich and Potter 1995). The effect of land-use change on CO_2 flux is obscure; some reports indicate an increase, while others indicate a decrease or no change in CO_2 emission rate, depending on the soil and climate condition and management methods (Raich and Schlesinger 1992). Secondary forest showed a higher CO_2 emission rate than paddy field and rice-soybean rotation in Kalimantan, Indonesia (Hadi et al. 2005). On the other hand, a study conducted at Kalimantan, Indonesia showed that conversion from secondary forest peatland to paddy field increased annual emissions of CO_2 and CH_4 to the atmosphere (from 1.2 to 1.5 kg CO_2-C m^{-2} y^{-1} and from 1.2 to 1.9 g CH_4-C m^{-2} y^{-1}), while change from secondary forest to upland decreased emissions of these gases (from 1.2 to 1.0 kg CO_2-C m^{-2} y^{-1} and from 1.2 to 0.6 g CH_4-C m^{-2} y^{-1}), but no clear trend was observed for N_2O (Inubushi et al. 2003).

Carbon dioxide flux is influenced by the amount and decomposition rate of C input and in addition by soil moisture in the tropical area. It is reported that CO_2 flux decreased with decreasing C-stocks and plant species richness (Murdiyaso et al. 2002). Davidson et al. (2000) reported the temporal positive relationship between soil water content and respiration rate at a primary forest in eastern Amazonia. The result in a Southeast Asian primary rainforest in Pasoh, Malaysia using eddy correlation method showed a positive linear relationship between respiration rate and soil water content (Kosugi et al. 2008). Seasonal and annual patterns of CO_2 exchange reveal that one of the main causes which induce the difference in NEE pattern between Amazonian and Southeast Asian rainforests was not the difference in daytime photosynthesis but the difference in ecosystem respiration related with dry and rainy seasons. The decrease of CO_2 uptake (increase of NEE) at wet period was also observed at this site, but did not form an obvious seasonality such as in Amazonian forests. Other soil condition, such as bulk density influences also the CO_2 flux. The CO_2 fluxes for young and old oil palm plantation in Jambi province, Indonesia were the smallest compared to natural and logged-over forests; rubber plantation, cinnamon plantation and grassland field. The finding suggests that the conversion from any land-use to oil palm plantation will decrease the CO_2 flux. In oil palm plantation, the soil is usually compacted by intense human activities, giving the soil relatively higher bulk densities. This increased density results in less undergrowth and litter layer in oil palm plantation. In addition to the land traction by heavy equipments before oil palm plantation, the lack of the respiration of undergrowth and litter layer makes the CO_2 efflux from the soil surface smaller than that from the other land-use types (Ishizuka et al. 2005). Soil carbon loss depends also on soil properties. SOM contents were found to decrease by 60% after 3–5 years of continuous cultivation of natural forest to slash and burn agriculture for sandy tropical soils, while it took 5–10 years for soils with a loamy texture (Feller and Beare, 1997).

2. How to increase Carbon Sequestration

2.1 Land uses that enhance Carbon sequestration

Organic carbon in tropical soils appears to be more easily degradable than that of temperate soils (Derpsch and Moriya, 1998) and hence increasing soil organic C content of soils of the tropics and subtropics is not an easy task (Lal and Bruce, 1999). To increase carbon sequestration, promising land-use systems and practices include agroforestry systems, fuelwood and fiber plantations, bioreserves, intercropping systems, and shelterbelts/windbreaks (Dixon et al. 1994). In northeast Thailand, soil organic carbon levels were increased down the soil profile with the establishment of pasture grass species (Noble et al. 2008). The soil organic carbon levels over the study period showed a 6 fold increase at >30 cm from the initial values, suggesting significant carbon sequestration, which was accompanied by severe soil acidification.

Reforestation is also of great interest. In Vietnam, forest cover dropped to 25–31% of the country area in 1991–1993, and then increased to 32–37% in 1999–2001 (Meyeroidt and Lambin 2008). The reforestation occurred at a higher rate than deforestation in the previous decades, and was due in similar proportions, to natural forest regeneration and to planted forests. The main reason were decollectivisation of agriculture, allocation of forestry land to households, and the development of market networks that transformed land use in the mountains (Meyeroidt and Lambin 2008). The mean carbon stock in forests followed a similar transition, decreasing to 903 (770–1307) Tg C in 1991–1993, and then increasing to 1374 (1058–1744) Tg C in 2005. Agroforestry and plantation systems employed by the Thai Forest Industries Organization sequester significant amounts of above- and below-ground C. The relatively fast growth of trees planted and the large land area covered by forest villages have resulted in approximately 0.01 Pg of above-ground C conservation and sequestration in Thailand since 1967. Preliminary estimates suggest that for every hectare of agroforestry system established, deforestation is offset by 5-20 ha, because shifting cultivators can sustainably derive food, fuel and fiber crops from agroforestry systems (Sanchez and Benites, 1987). Thus, C is also conserved by slowing deforestation (Dixon et al. 1994)

2.2 Management methods that enhance Carbon sequestration

Management methods can also increase carbon sequestration in individual land uses. Increase in organic matter application increase the soil organic C for several years till a stable condition of C stock for soil and above ground is established (IPCC 2007). In a maize field in northeast Thailand, application of cattle manure increased the soil C stock from 11.0 to 18.2 Mg C ha^{-1}, and non tillage system increased it from 13.3 to 15.9 Mg C ha^{-1}, whereas soil C stock of conventional cultivation did not change (Matsumoto et al. 2008). Smart intercropping can also increase the C sequestration. In Indonesia, two main companion crops; cassava (Manihot esculenta Crantz) and maize (Zea mays L.) were investigeted for intercropping with kayu putih (Melaleuca leucadendron L.) plantation. Cassava tuber production declined in older stands suggesting that cassava is not suitable as a companion crop in older stands. On the other hand, maize produced a reliable yield throughout stand growth and contributed equally or more to returned biomass than cassava in older stands. These characteristics suggest that maize is a good companion crop for kayu putih. The practice of returning biomass to the soil contributed to soil development. With increasing stand age, SOM in the lower layer increased, while in the upper layer SOM remained relatively constant. In the oldest, 40-year-old stands, SOM in the lower layer reached values similar to the upper layer. The practice of returning crop biomass makes soil conditions in older stands more suitable for growth of deep-rooted kayu putih trees (Budiadi et al. 2006). Pruning and the fate of the application of pruned branches can increase C-Stock in Gliricidia sepium forest. Pruning decreased standing biomass but its return to soil increased the soil C stock. Considering this tradeoff relation, 25% pruning and highest proportion of the pruned material to soil had the highest increase in total C-stock increase. Selling the pruned material as fuel are of economic interest and incentives are necessary so that farmers will adopt management methods increasing C-stock (Wise and Cacho 2005)

2.3 Socio-Economic aspects of adopting land use practices that enhance Carbon Sequestration

To adopt those land uses and management methods increasing C sequestration, incentive to local stakeholders is crucial. Several studies conducted in the tropics have demonstrated the positive impacts of residue retention or manure application on soil organic C concentration as well as increase in crop yield. These include the studies conducted in India with various crops (Murdiyaso et al. 2002). Similarly, some studies conducted in India have also reported that cropping systems with different combinations of fertilizers and manures contributed towards an increased soil organic C (Murdiyaso et al. 2002). A study investigated a hedgerow-intercropping system in the presence of carbon-sequestration payments using a bioeconomic modelling framework for South Sumatra, Indonesia. It was found that fertilizer improves the productivity and sustainability of the system and it was either optimal to grow crops (Zea mays) alone, provided 225 kg ha^{-1} y^{-1} of fertilizer is applied, or to completely convert to growing trees (Gliricidia sepium) if fertilizer is not used. This decision depends on the relative prices for crops and carbon (Wise and Cacho 2005). A study conducted in Kalimantan, Indonesia analyzed the incentive to increase C sequestration at landscape and smallholder levels. The highest value for predicted additional C storage in the wider landscape did not coincide with the best results for local livelihoods, but in each of the case studies the results for a 'programmatic' removal of constraints to profitable smallholder tree-based production systems was more attractive than a 'prescribed' tree planting in designated project areas (van Noordwijk et al. 2008).

3. Other green house gasses

3.1 Nitrous oxide emission

There are also other greenhouse gases emitting from soils such as nitrous oxide (N_2O) and methane (CH_4). Deforestation and/or biomass burning could have a pronounced impact on N_2O emissions in the short term (Ishizuka et al. 2002) and in the long term (Keller et al. 1993). Logging in tropical rain forests in peninsular Malaysia increases the emission of CH_4 and N_2O for at least 1 year after logging, thus potentially contributing to global warming (Yashiro et al. 2006). However, there was no difference in soil CO_2 flux even though soil temperature at the logged sites was higher than at unlogged sites (Yashiro et al. 2006). Acacia mangium soils function as a larger source of N_2O than natural forest soils in the adjacent province in Sumatra, Indonesia during the relatively dry season, while CO_2 and CH_4 emissions from the Acacia mangium soils were less than or consistent with those in the natural forest soils (Konda et al. 2008). Comparing forest, potato field and tea garden, tea garden had the highest N_2O emission than other crops in Kalimantan, Indonesia (Yashiro et al. 2006). Industrial plantations of fast-growing tree species have recently been expanded, both to supply wood and to fix atmospheric CO_2. In particular, fast-growing leguminous tree plantations have been widely introduced into tropical Asia (FAO, 2001). Leguminous trees may lead to high N_2O fluxes because N cycling in the soils is accelerated by the high N content in their litter (leaves, branches, dead roots) due to their symbiotic N fixation (Konda et al. 2008). Despite those concern about increased N_2O emission, some research reports little change due to land use change. The long term conversion from tropical forest to rubber plantation was found to have little effect on N_2O emission in Jambi province, Indonesia (Ishizuka et al. 2005) and the influence of land use change on N_2O emission is still obscure due to the complex mechanism of N_2O formation which will be discussed below.

Nitrous oxide is produced through two processes: denitrification, which requires anaerobic condition, and nitrification, which occurs under aerobic condition. Positive correlation exists between the N_2O emission rate and NO_3 pools at the logged sites in peninsula Malaysia. N_2O production correlates with nitrogen availability in soil, because nitrification and denitrification rely on $NH4^+$ and NO_3, respectively (Bouwman, 1990). The N_2O production of Malaysian soil investigated by incubation was increased by decreasing the C/N ratio of the organic N sources and by increasing the moisture content (Khalil et al. 2002a). That result indicated that the acid soil could be a potential source of N_2O if treated with urea/KNO_3 and easily decomposable organic matter under favorable moisture conditions (Khalil et al. 2002a). Similarly, the N_2O emissions for maize-groundnut-fallow system in Malaysia depended on the amounts and types of N. A maximum peak of N_2O flux was detected at 2 weeks before maize sowing amended with chicken manure, showing a persistent influence on N transformations and N_2O release. The mineral N from either applied source became low by 2 to 4 weeks, coinciding with the small N_2O fluxes. The N_2O flux significantly correlated with the mineral N and water-filled pore spaces (Khalil et al. 2002b). While those studies indicate the contribution of both denitrification and nitrification, studies exist indicating more contribution of nitrification than denitrification. The N_2O fluxes of different soil types of Jambi province, Indonesia were correlated with the nitrification rates of soils of 0–5 cm depth. There was no clear relationship between N_2O flux and the soil water condition (Ishizuka et al. 2005). To reduce N_2O emission, application of nitrification inhibitor is a promising method. The application of nitrification inhibitor reduced the N_2O emission by half (Jumadi et al. 2008) or even one thirtieth for maize fields in Kalimantan, Indonesia (Hadi et al. 2008).

3.2 Methane emission

Natural forest can act as a sink of CH_4 due to oxidation of CH_4. The most important factor controlling the CH_4 uptake rate is the gas diffusion coefficient, which is determined by soil texture (Born et al. 1990; Verchot et al. 2000). Land-use change from forest to active pasture caused a decrease in the CH_4 uptake rate (Keller et al. 1993; Keller and Reiners 1994), although degraded pasture consumed more CH_4 than primary forest (Verchot et al. 2000). The growth of rubber trees coincides with the increase of a hot spot of CH_4 emission. The CH_4 uptake rate decreased for several years after oil palm plantation (Ishizuka et al. 2005). Compared to the natural forests, land use change to cacao agroforestry systems led to higher N_2O emissions and lower CH_4 uptake with age of cacao agroforestry systems for Sulawesi, Indonesia (Veldkamp et al. 2008) Compare to upland crops, agroforestry has still higher CH_4 uptake rate and agroforestry was found to enhance CH_4 sink potential in the landscape in Thailand (Dixon et al. 1994). Controlled release of fertilizer increased the CH_4 uptake at maize fields in Kalimantan, Indonesia ((Jumadi et al. 2008).

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Chapter 3

Governing ecosystem services from upland watersheds in southeast Asia

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Introduction

The ecosystem services derived from upland watersheds are important to the well-being of people living in them, others living downstream and to society more widely (Millennium Ecosystem Assessment 2005, Braumann et al. 2007, Lebel et al. 2008). Perceived or realized services often include providing food, timber, fuel-wood and non-timber products, pollination and pest control for crops, water for irrigation or hydropower, sites for cultural activities, flood protection, buffered base flows, carbon sequestration and water filtration. The specific benefits people obtain from a watershed are highly dependent on the mixture of ecosystems present, landscape structure and social contexts.

As a consequence of this variety of valued services, pursuing multiple management objectives is a practical reality for most upland watersheds in Southeast Asia[i]. It is also a source of contestation and conflict. Managing a watershed for one particular service or user may result in trade-offs in provision of other services and for other actors. Local communities and governments have frequently tried to prioritize, eliminate or integrate use of different services with combinations of plans, rules, incentives and information (Lebel and Daniel 2009).

Spatial planning has been the favored approach. Governments have devised classifications for land, forests and watershed and used these to restrict or encourage particular activities (Laungaramsri 2000). Upland communities have also made spatial plans, but with typically more flexible and overlapping systems of rights for using different resources – that is, with a less strictly territorial and more socio-cultural perspectives (Daniel and Ratanawilailak 2010).

An important adjunct of plans is to associate landscape units with rules of use and responsibilities. Rule-making can be by, or in consultation with, users or it can be dictated by more remote authorities. Co-management models have often been promoted because they provide opportunities to consider services valued at different levels.

Although many rules are dos and don'ts, alternatives that create incentives may be more effective in some situations (Wunder 2007). Markets for ecosystem services have been established in various parts of the world as an alternative to regulations to encourage conservation of valued services. Their performance depends on institutional design details and socio-political contexts (Wunder et al. 2008b).

The quality of information about services and impacts of use and management is crucial to most efforts at governing them but often receives insufficient attention (Carpenter et al. 2009). Payments for ecosystem services, for example, require a good understanding of which actions actually secure provisioning and indicators that can be monitored (Engel et al. 2008). In many cases unambiguous, place-specific, evidence that particular land-covers provide a service is lacking – for example, flood protection benefits (Bruijnzeel 2004, Locatelli and Vignola 2009, van Dijk et al. 2009).

Local, experience-based knowledge and scientific knowledge are not as frequently integrated as needed (Berkes 2009). Building awareness and understanding through integrated assessments and monitoring are crucial (Lele 2009) but will never be a substitute for politics around which services and users should be prioritized.

In this paper we focus on institutional and political dimensions of governing ecosystem services from upland watersheds in Southeast Asia. We build on earlier, much shorter, review of experiences from the global tropics (Lebel and Daniel 2009) by considering in much more detail empirical evidence from Southeast Asia. The chapter is organized around the four themes: plans, rules, incentives and information.

Plans

A common approach to managing the complex set of services from upland watersheds is through spatial land-use planning, zoning some areas for biodiversity conservation, watershed protection, forestry, agriculture, tourism or multiple uses. Most governments in south-east Asia have adopted policies for controlling land-use in upland watersheds. The extent to which users and residents are involved in planning varies as does the influence of plans on practices.

Protected areas

Most conservation policies and strategies of governments are founded on the idea of separating people from their environments in systems of protected areas (Chopra et al. 2005). A discourse around the benefits of ecosystem services has usually been added to early justifications based on biodiversity and recreational or cultural values, focussing on either downstream communities or more recently on global environmental benefits of reduced deforestation. The protected area approach argues that conserving natural ecosystems in a close to intact state will maintain a full suite of ecosystem processes, and thus, the full range of services, which forests or other forms of native vegetation provide.

Vast areas of the tropics were declared as protected areas between 1980 and 2005 (Naughton-Treves et al. 2005). Indonesia has set aside about 12.5% of its land area in protected areas for nature conservation; Malaysia about 31% (EarthTrends 2003, UNEP-WCMC 2003); Thailand about 19% percent for conservation (ICEM 2003c, IUCN 2007). The practice of allocating large areas as conservation areas and parks spread in the 1990s to other countries in the Mekong region. Lao PDR has established an extensive set of protected areas covering more than 21% (ICEM 2003a) and Cambodia 18% (ICEM 2003b). While most protected are located in the uplands (as lowland areas have already been cleared of native vegetation) the extent to which use of forest goods and services is restricted varies among countries (Thomas et al. 2008). The effectiveness of management also varies widely with many parks existing only on paper, promised local benefits to residents from tourism often smaller than expected, and conflicts created over access to land, resources and services (Roth 2004a, Naughton-Treves et al. 2005).

As of 2008, Thailand's Royal Forestry Department had established more than 200 protected area units covering approximately 19% of the country's land area. The government of Thailand intends to increase protected area systems to 30% of the country by 2016 (Trisurat and Pattanavibool 2008). The implications for the upland communities, particularly ethnic peoples, living and farming in protected areas declared as national parks, wildlife sanctuaries and watershed areas are huge and tensions involving farming communities fighting state forest land classification have become increasingly frequent (Wittayapak 1996, Poffenberger 1999). At larger scales, the outstanding challenge is that benefits from existence value of biodiversity frequently do not align with the value of habitat conversion to agriculture for local poor communities (Fisher and Christopher 2007).

However, parks have failed at forest conservation; special deals are possible to convert land for tourism and even personal use. In Thailand's Khao Yai National Park, a proposed golf course and resort that began construction was halted only after protests (Laungaramsri 2002a, Ross 2003). Powerful military or political figures can acquire "protected" areas or land designated for resettlement of displaced villagers but typically remain un-investigated (Phongpaichit 1999).

Studies of a biodiversity conservation in Ruteng Park on Flores Island in Indonesia provides a closer look at the links between the conservation of biodiversity and the livelihoods of rural people who live on the fringes of the parks and protected areas. An early study demonstrated the economic value of drought mitigation services to farmers downstream of forest in upland watersheds inline with policies of the Indonesian government and park (Pattanayak and Kramer 2001). A subsequent study linked forest cover to prevalence of diarrhoea presumably through impacts on drinking water quality illustrating another under-appreciated service of the park (Pattanayak 2007). Parks can provide multiple ecosystem services and benefits.

Forest and watershed classifications

Control and authority over forest areas of most countries in Southeast Asia rests with the national or state government. In Indonesia, the Philippines and Thailand, state control over forests has grown since the establishment of forest service agencies during the late 19th and early 20th centuries. Governments have exerted authority over forests through land classification and zoning schemes, for example, by attaching regulations prohibit local access or use depending on whether a parcel of land is classified as "forest" or "upland" (Lebel et al. 2004).

In Thailand forests are defined by the 1941 Forestry Act as "*land without occupants*" and as "*land with no right-holders*" (Forestry Act 1941). As land areas become classified as '*forest reserves*', there is a great deal of ambiguity of ownership of agricultural lands in rural areas particularly in collectively-used lands such as community forests, sacred forests, and fallow farmlands (Sato 2003). Agricultural land in forest reserves make up the majority of agricultural lands in Thailand in areas typically classified as degraded forests. Only a minority of private land holdings used for agriculture have full title deeds. Often agricultural land holdings do not have the concept of ownership in the modern sense and are limited to either usufruct or *'sithi krobkrong'* and squatter's rights or '*sitthi japjong'* (Sato 2003). The changes made to legal categories and procedures for land over the past several decades are an important source of contemporary conflicts over land. The current legal categories of rural and forest land in Thailand illustrate some of the governance problems created by categories and definitions driven by interests in a narrowly framed set of services.

The National Forest Reserve Act of 1964 attempted to centralize forest control; by 1985, the RFD declared approximately 45% of the country's total area as forest reserves. But lands designated as state national forest reserve often had no trees or already had people residing in those areas (Hirsch and Lohmann 1989, Flaherty and Jengjalern 1995).

The RFD's designation of forests as being driven by the expansion or maintenance of its own power and control over territory (Vandergeest and Peluso 1995) does not completely explain official motives but may also include departmental factionalism. For example, designation of reserved forests before 1938 that was undertaken by the authority of local administrative sections could not realistically expand the authority of RFD. Some regional forest officers enthusiastically urged the designation of reserved forests at that time because they thought if they did not do so, the forests would disappear. Thailand's foresters were also conscious of the need for spatial enclosure of forest lands for so-called scientific forestry (Wataru 2003).

Other Mekong region countries follow systems similar to that of Thailand with the difficulty that the state spatial classification system finds it unable to incorporate other types of land-uses such as swidden rice farming systems.

Swidden systems are a mosaic of different-year fallows and secondary forest areas some of which subsequently also are transformed into upland rice fields and then back again into fallows. Fallow forests that are part of the swidden rice cultivation cycle of upland communities cover large parts of Burma/Myanmar, Cambodia, northern Thailand, Lao PDR and Vietnam. Secondary forests, which regenerate on the fallow swiddens, are rich in tree species and complex with respect to stand structure. The farm-forest fallow-swidden ecosystem (including the trees and wildlife species) is part of an extensive indigenous knowledge system. But as swidden cultivation is actively discouraged by officials, the system is undergoing many changes and also increasingly being replaced by permanent rice farming. The land use changes are causing a reduction in the area covered by fallow forest ecosystem with subsequent negative impacts on biodiversity (Rerkasem et al. 1994, Schmidt-Vogt 1998, Laungaramsri 2002b, Walker 2004).

State management uses positionality to make strictly bounded static spatial categories such as “conservation forest” and “village land”. Categories of this type can be easily delimited on a map and made legible to future officials. Conversely, swidden space and village management does not fit since it does not take the shape of straight lines but instead follows streams and mountain ridges, contains rough edges, and often defines location in relation to another's field or a landscape marker (Roth 2004b).

Concerns around landslides, floods, soil erosion and sedimentation have driven much research and policy on agriculture on sloping lands (Blaikie and Muldavin 2004a, Forsyth and Walker 2008). A recurrent rationale for policies and projects has been that maintaining or increasing forest cover will secure key ecosystem services – often without much specific attention to tree species involved or impacts of alternative land-uses. The scientific evidence base for many services, like flood protection, however, often remains modest and controversial (Bruijnzeel 2004, Locatelli and Vignola 2009, van Dijk et al. 2009). Scientific knowledge about watershed services is frequently used selectively or misrepresented in justifying upland policies (Forsyth 1996, 1998, Walker 2003, Blaikie and Muldavin 2004b).

In Thailand, watershed classification (Chankaew 1996), like the definitions of forest lands, was also used as instruments to strengthen state control of upland resources, restrict expansion of farmlands in upland catchments and threaten highland farmers with resettlement (Vandergeest and Peluso 1995, Laungaramsri 2000). This is illustrated in the ground where watershed classification can even lead to entire provinces or districts in northern provinces of Thailand coming under strict conservation status. For instance, most of Mae Hong Son province falls under the highest order of protection Watershed 1A, thus prohibiting all settlement and agriculture, and placing huge stress on the communities who live and farm in the province. In practice implementation of the classification has been left incomplete as the Thai state does not have the capacity, political support or available land to resettle all upland farmers into lowland areas (Walker and Farrelly 2008).

Watershed classifications across the region are grossly similar with classes of high to lower restrictions on uses. Most areas with restricted classifications are in the uplands (Thomas et al. 2008). The Watershed Classification Project carried out by the Mekong River Commission Secretariat between 1989 and 2001 elaborated a basin-wide classification indicating the sensitivity of watersheds with regard to resource degradation (mainly by soil erosion). It aimed to develop a decision-support tool. Along with the classification, the project produced general recommendations for sustainable land use in each Watershed Class. For instance, for "Watershed Class 1: Protection Forest Areas" with very steep slopes and rugged landforms, commonly uplands and headwater areas, the project said that as a rule, these areas should be under permanent forest cover. Notably, the project also added a caveat that "*account needs to be taken of traditional rights and land use practices*" (Heinimann et al. 2005).

State schemes for classifying and planning land-uses do not correspond closely with actual provision of ecosystem services; swidden, multi-species orchards, and agroforestry may yield more services than monocrop plantations labelled as forests and assumed to be service-rich (Cairns 2007, Bhagwat et al. 2008, Xu et al. 2009). In Southwestern China, indigenous land-use practices may be more beneficial to long-term conservation objectives than protected areas (Sharma and Xu 2007, Xu and Melick 2007). In the typical, dynamic and mosaic landscapes of much of upland Southeast Asia various ecosystem services are not coincident in space or time. Hydrological services like base stream flows at the end of the dry season and flood protection services during the wet season may both be valued even when how to secure them is not fully understood (Forsyth and Walker 2008, Neef and Thomas 2009).

Participatory land-use planning

A recurrent challenge for planning is getting adequate information about ecosystem services at scales relevant to decision-making (Turner and Daily 2008). Local knowledge is often crucial but only available if planning agencies allow space for meaningful local participation (Thomas 2006).

A good example is the work of ICRAF, CARE and local government and non-government organizations in the Mae Chaem watershed of Chiang Mai province (Thomas 2005). Such activities are also a helpful background to more bottom-up processes of basin management in areas beyond the rural-interface and merging into peri-urban or desakota landscapes. When multiple stakeholders including scientific and local experts are involved, underappreciated services can be better understood, as for example, from Ruteng Park described earlier.

Institutional frameworks such as watershed management committees, organizations or networks, that may be mandated by government or emerge independently, can help solve local resource allocation problems. However, such organizations may not have much formal decision-making authority or budget but take on basic planning, conflict resolution and negotiation functions (Thomas 2006). In the Upper Ping river basin, the Thai government established several river sub-basin committees that each adopted slightly different committee structures and activity plans to deal with the range of stakeholders and issues important in their sub-basin (Thomas 2006). The challenge was introducing new organizations with recognized cross-sectoral planning mandates in a context where individual agencies and water user groups already had well-organized networks and coalitions (Thomas 2006, Mollinga et al. 2007). Local communities also make plans to manage their watersheds (Wanishpradist 2005). Overall, however, it is rare to find direct involvement of stakeholders in analysis of ecosystem services as a basis for informed negotiations and decision-making (Fisher et al. 2008).

A range of accounting techniques is available to help people understand dependencies on ecosystem services from generalized ecological footprints through to valuation of specific services (Jenerrete et al. 2006, Patterson and Coelho 2009). The ecological basis of many exercises, however, remains tenuous as context specific evidence is frequently lacking or inadequate. The importance of participatory and deliberative methods for accounting and evaluation is likely to grow (Spash 2007) especially where knowledge about hydrological services is strongly contested (Forsyth and Walker 2008).

Classifications reflect the interests of those who build them. There is a need to re-conceptualize land-use planning for conserving ecosystem services as a process of joint assessment and negotiation. Current land classifications produce tensions and conflict; they need to be adjusted to fit "prior use" of areas currently classified as "forest land" irrespective of the quality of forest now and reward good management rather than penalize it. Validation is possible with aerial photograph and satellite-based remote sensing.

Rules

Rules and regulations underpin plans helping to define rights of access and use of ecosystem services and responsibilities for their management. Institutional instruments are diverse including quotas, licenses, concessions, seasonal bans as well as other customary rules, taboos and norms.

Property rights and land tenure

Whether an ecosystem service is a private, public, club or common good makes a difference to how they might be governed (Engel et al. 2008, Patterson and Coelho 2009). Individual property rights for services which are excludable and rival are particularly useful to farmers as they encourage investment in land – for example to grow trees which may not provide returns for many years. Formal title deeds are also useful as collateral in obtaining loans (Walker 2006).

As public goods are used more intensively they can become rival goods that need other institutions to be managed sustainably (Fisher et al. 2008). Pre-existing private property rights may hinder efforts to manage for services that are common pool resources – rival, but non-excludable – and coordination mechanisms are needed (Patterson and Coelho 2009).

Some hydrological services like drinking water supplies from springs or streams are managed as club goods (Engel et al. 2008). Others are treated as common property of a sub-watershed, village or even a group of neighbors. Rules of use in community forests typically specify amounts or seasons during which valued but scarce forest resources can be collected (Cairns 2007, Kerr 2007). Rules for common pool resources are often flexibly bundled, so that allocation of scarce bamboo clumps or trees with resin or others needed for spiritual ceremonies might be allocated to individuals or households whereas access to re-growth might be open to all for grazing (Lebel 2005). Hydrological services like flood protection or dry season base-flows requires coordination between upstream and downstream users and findings ways to secure mutual benefit (Kerr 2007).

The conventional logic that formal land tenure enhances sustainable land and forest management is challenged by experiences in Thailand (Daniel and Lebel 2006). For example, although ethnic minority groups in the Northern uplands commonly do not have permanent land use rights, long-term investment in land resources is common practice (Neef et al. 2000). For ethnic people in more remote uplands, formal access to land may often be less important or desirable than access to the Thai citizenship cards and the capacity and flexibility of household members in exploiting new income sources both on- and off-farm (Knupfer 2002, Thomas et al. 2008).

A common strategy of farmers in trying to prevent land claims of state forestry officials where local rights are not otherwise recognized is to plant fruit trees or tea shrubs, as it was believed that forestry officials would not claim land that has already been planted with perennial crops. Another response was to convert rain-fed swidden rice fields or fallows to permanent paddy fields or other cropping systems (Neef 2001). Additionally, some communities try to avoid land losses through "appeasing" of the forest officers by being active in "forest protection" through building firebreaks and reforestation (Knupfer 2002).

Lao PDR, Vietnam and China went through periods of collectivization and then re-allocation of agricultural and forest land so some of the tenure issues are different than those in Thailand (Thomas et al. 2008). Land has been allocated to both individuals and villages. The Lao government has had a particularly forceful policy of ending swidden cultivation.

Overall, it is hard to draw strong conclusions on the relative performance of formal and informal arrangements. In remote areas, a lot depends on local institutions and relations with local officials rather than formal land certificates and regulations (Walker and Farrelly 2008, George et al. 2009). Both formal and informal tenure can matter, and their interplay can be positive with respect to livelihoods and environmental outcomes. With proximity or when more profitable opportunities arise – for instance related to eco-tourism or logging concessions – ambiguities in land tenure often become more problematic (Wunder et al. 2008a). Clarifying property rights can be an important aspect of governance of upland watershed services, but formal land tenure is not necessarily a pre-requisite to establishing sustainable management systems for ecosystem services, especially where informal, use rights are locally recognized and respected.

Community-based management

Property rights may be vested in communities rather than households and individuals. Community forests have become an arena for spatial negotiation of land and forestland use between the state, timber companies and local communities as well as a means of promoting local participation in forest management. But many community forest programs are failing because external factors promoting forest degradation are stronger.

In Cambodia, ministerial order recognizing forest sites as potential community forestry areas is the first step towards formal recognition of community management of forest areas. In December 2008, more than 100 villages in several provinces were granted formal management of about 127,000 hectares of forest in 87 forest sites by Cambodia's Minister for Agriculture, Forestry, and Fisheries. Another 37 potential community forest areas covering 18,000 hectares were already recognized in Siem Reap in 2007 bringing a total of 145,000 hectares of forest under recognized local management. The next step of formal registration through signing a CF Agreement with the Forestry Administration, would give communities full legal access and management rights over local forest areas for 15 years, protecting these areas from commercial and other outside interests. It also enables some of Cambodia's poorest people to benefit economically, with rights to use forest resources including timber (RECOFTC 2009).

In their comprehensive review of community-based forest management in the Philippines, Lasco and Pulhin (2006) conclude that the strategies of planting trees in farms and landscapes has had largely positive environmental effects, for example, for soil and water conservation, carbon sequestration (also see section below) and biomass production. Other studies of complex agro-ecosystems like benzoin and rattan gardens in Indonesia highlight how reduced intervention in the system can lead to ecological succession-processes increasingly similar to those found in native forests after disturbance and thus important to biodiversity conservation as well as productive use (Garcia-Fernandez and Casado 2005). Agroforestry practices using trees and cover crops greatly reduce soil erosion compared to monoculture plantations without groundcover (Sidle et al. 2006).

Management practices cannot be understood separate from their social example. For example, *miang* forest areas in Nan province of northern Thailand, important for supplying tea, are not only maintained as a watershed forest comprising part of the *muang fai* traditional irrigation system, but also serve as an agro-ecotourism centre bringing in cash income and supported by the local government (Wittayapak and Dearden 1999).

Co-management for resource use can produce differing tensions depending on the policy emphasis on village, households or individuals. In Vietnam, for instance, during the 1950's and the 1960's, the national government encouraged villages to formulate cooperatives, though the membership of the cooperatives and decision-making processes may have continued to reflect traditional modes of operation. By the 1960's and 1970's, the government tried to establish multi-village cooperative units or communes. However, the 1980's brought policies that shifted away from collectivization, returning authority to the village, and, most recently, to households. This may make it possible for villages may regain greater autonomy, creating opportunities for traditional institutions to re-establish their role in resource-use decision making. Yet government policies and programs, while de-emphasizing collectives, give little recognition to the role of the traditional villages. Instead, these new policies and programs emphasize empowering the household or individual (Sowerine et al. 1998, Sowerine 2004).

Co-management arrangements with state agencies, firms and other actors are institutionally diverse. One of the recurrent factors important to success is networks of trust which support stable social relations (Lele 2004, Armitage et al. 2009, Berkes 2009). In the context of upland watersheds with their dynamic and complex mix of ecosystem services valued at multiple scales (Lebel et al. 2008) the challenges and rewards are particularly high.

Logging concessions

European forestry influences are evident in state forest management practices that follow scientific forestry norms developed in the eighteenth century and which were focussed on supplying colonial powers the raw materials to industrialize (Bryant et al. 1993, Lang 2000, Contreras 2003). In mainland Southeast Asia, the colonial British Empire dominated and controlled the teak trade in India, Burma (Myanmar) and Thailand. In Vietnam, Laos and Cambodia it was the French. Colonial forest centralized authority in national capitals, using licenses, concessions, and military force as needed to gain control of forest resources.

Southeast Asian governments and their corporate counterparts have viewed logging as an important source of power and revenue (Pasong and Lebel 2000, Dauvergne 2001, Butler and Laurance 2008). Revenues from timber exports in the Philippines in 1950-1969 were used for rebuilding the country from the devastation of wars. In Malaysia, timber rents make a significant contribution to growth, exports, savings, investment, government revenue and fiscal capacity. Forestry is a dominant sector in the Laotian economy: despite restrictions on logging and high export taxes implemented in 1989 – which decreased its share of total exports by 36 percent – timber and wood products remained the major export (replacing hydroelectricity). In 2000, the forestry sector contributed 5 percent to GDP increasing from 3.4 percent in 1990 (FAO 2002). In Cambodia, both the Khmer Rouge and afterwards the elected government exported timber to Japan, Thailand and Vietnam (Billon 2000).

The Indonesian government took control of forest resources in 1967 distributing over 60 million hectares in timber concessions to private companies often connected to military leaders (Pasong and Lebel 2000, Dauvergne 2001). The industry is controlled by only a handful of players; Barito Pacific, for example held more than 10 percent of the concessions and control over about 6 million hectares.

The management of forests in Indonesia is based on a land use classification which distinguishes protected forests, limited and general production forests, and conversion forests and areas for parks and reserves (Dick 1991). Clear felling is allowed in conversion forests, and transmigration settlements are developed from contiguous logged areas. In production forests, concession period by timber and logging companies had been extended to a 35-year harvesting cycle to induce replanting and payment of the appropriate fees from forest exploitation to the government.

The need to generate foreign exchange for debt servicing and the increased demand for raw industrial materials both in the domestic and international markets have helped induce the replacement of complex forest ecosystems by monoculture plantations. The pulp and paper industry for instance in Indonesia has expanded rapidly since the 1990s. Some estimates suggest that as little as 10 percent was actually harvested from plantation timber with the rest coming from illegal cuts in natural forests. Forests were also cleared to plant fast-growing species (Barr 2001). This conversion to tree plantations has resulted in forest loss and internal displacement, increased social conflicts over land, and worsened small-landholder tenure insecurity (Lang 2002).

In Lao PDR, the rising price of natural rubber products due to the demand of the Chinese market over the last decade has attracted rubber plantation investors from China, Thailand and Vietnam to seek land concessions all over the country (Manivong and Cramb 2007). Throughout the region one of the largest concerns is the impacts on water-use as rubber is a water-demanding crop and many of the areas where it is expanding are highly seasonal with dry season water scarcities already a constraint on agriculture (Xu 2006, Mann 2009, Ziegler et al. 2009).

Logging bans

Several countries have invoked logging bans in native forests often in response to serious flood events (Daniel 2005, Xu et al. 2007).

Until the 1989 logging ban, the Thai government gave concessions to companies to log large parts of the forest area that lay outside national parks and wildlife sanctuaries. Indiscriminate logging practices usually led to continuing deforestation where 30-40 percent of the residual younger trees were destroyed. Hence, most logged-over forest areas became quickly degraded, and were further exploited by human activities as rural communities and land speculators obtained access through the logging roads (Kashio 1995a, 1995b).

After the 1989 logging ban, the Thai government promoted a wood import policy and Thai logging companies expanded logging concessions into the neighbouring countries of Laos, Cambodia, and Myanmar (Daniel 2005). The logging of neighbouring country forests has also resulted in illegal logging operations in Thailand's forests, particularly along the borders (Cooper and Palmer 1992). Illegal logging in the forests of the Salween National Park and the Salween Wildlife Sanctuary along the Burma/Myanmar and Thai border was one of the most well-known timber scandals in the post-logging ban period.

China's logging ban was introduced in 1988 alongside several other major policies, like the sloping land conversion program of 1999, that combined enforcement and incentives to increase forest cover on sloping lands (Bennett 2008). These national policies have had major impacts on livelihoods and land-uses in the ethnically diverse sub-tropical watersheds of Yunnan Province (Xu and Melick 2007, Xu et al. 2007, Xu et al. 2009) leading to, for example, the almost complete elimination of swidden cultivation by the Hani and its replacement by rubber (Xu et al. 2009).

Incentives

Market-based instruments or other forms of incentives which reward good management practices are an alternative to spatial planning and regulations. Here we look specifically at payments for ecosystem services and certification schemes.

Payments for ecosystem services

Payments for environmental or ecosystem services (PES) have emerged as an alternative or complement to spatial planning and regulatory approaches to conservation (Wunder 2007, Engel et al. 2008). PES schemes are voluntary transactions in which an environmental service is bought by a buyer from a provider if and only if the provider secures service provision (Wunder et al. 2008b). Such schemes share similarities to eco-certification of products and other incentive-based mechanisms, like environmental taxes or subsidies (Engel et al. 2008, Jack et al. 2008). Common challenges include clarifying property rights, getting prices right and linking actions to compensation (Fisher et al. 2008). PES appears to be most relevant when an ecosystem service is under threat in marginal lands where opportunity costs are modest and land claims clear (Wunder 2007).

For PES, the distinction of whether the ES provided are public goods or those in which they are not is an important distinction. Not all ES are pure public goods, i.e. consumption by one user does not affect consumption by another; many other ES are, in fact, either excludable or rival in consumption. In particular, many water services are "club goods" where only those holding water rights or those located in a well-delineated watershed benefit. This has implications both to identify the users and arrange for them to pay for service provision as well as to direct the benefits to the providers. This can affect questions of equity as well (Corbera et al. 2007).

To date only a few such schemes have been operating for a significant period in Southeast Asia; quite a few of these deal with watershed protection and related services. Many are related to the program RUPES or "Reward the Upland Poor for Environmental Services" (Swallow et al. 2007, Van Noordwijk et al. 2007, Leimona et al. 2009).

In the Philippines, concern over loss of biodiversity ranked very high among stakeholders in designing a PES program in the Peñablanca Protected Landscape. The PES program thus was initiated with high conservation, cash payments and investments in carbon crediting as the most beneficial option. The design of the PES program showed that the linkages between land use and the level of environmental services was crucial to the sustainability of the PES program. The financial, economic, social and environmental factors were of equal importance in designing the PES program (Bennagen et al. 2006).

In northern Thailand, upstream, ethnic minority, communities are expected to conserve upland watersheds, stream flows and biodiversity while also simultaneously being widely perceived by lowland communities and policy-makers as a threat to, rather than providers of, ecosystem services (George et al. 2009, Sangkapitux et al. 2009). A study in the Mae Sa watershed found that payments for water resource by downstream resources users was possible with upstream farmers willing to adapt their farming practices given adequate compensation (Sangkapitux et al. 2009). While building awareness about ethnic communities' sustainable practices around ecosystem service projects could help change lowland perceptions, discrimination against upland minorities continues due to power and control over the uplands residing with lowland Thai policy makers.

Wunder et al. (2008b) reviewed a sample of programs invoking payments for environmental services that included several studies from tropical South America and found user- as opposed to government-financed programs were better in terms of fit to targeted beneficiaries, local conditions and needs, and monitoring. China, Mexico and Costa Rica each have large programs giving payments to landowners for changing land-uses (Sanchez-Azofeifa et al. 2007, Jack et al. 2008).

Rewards or compensation does not have to be direct cash payments to individuals; they could be non-monetary payments to groups or as guarantees of privileged or secure access (such as land tenure) to services or other resources like training (Leimona et al. 2009, Neef and Thomas 2009). Non-financial incentives may be more important to poverty alleviation than direct cash payments (Leimona et al. 2009).

In the complex resource management situations typically found in upland watersheds introducing new markets for ecosystem services needs to consider carefully existing access rights as well is who is excluded and who will benefit or be at a disadvantage (Corbera et al. 2007, Mollinga et al. 2007). Poor, marginalized and otherwise vulnerable groups are often more dependent on ecosystem services and have relatively low opportunity costs than others (Jack et al. 2008) but their capacities to engage may also be limited. Poor farmers in Vietnam uplands with small holdings were unlikely to join reforestation schemes unless compensation was adequate to cover loss of food production (Jourdain et al. 2009). Moreover, when there are many poor small providers, transaction costs can be high and thus not competitive (Jack et al. 2008). Studies of two carbon sequestration projects in Mexico showed how women and poorest were excluded from designs and that outcomes reflected political affiliations with project managers (Corbera et al. 2007). Non-participants in ecosystem services projects may also be impacted adversely, for instance, when landless farmers lose access to common pool resources (Wunder 2008). Although evidence about welfare impacts remains modest the emerging findings suggest that PES programs, on balance have had relatively small positive effects, and are unlikely to become central to poverty alleviation efforts (Wunder 2008).

Ultimately, how rules are arrived at may matter as much as their final form. Thus, who runs a project is a crucial feature of PES schemes (Corbera et al. 2007, Wunder et al. 2008b). Intermediaries may be created by service buyers or sometimes a third party. Non-governmental organization may be helpful where farmer's groups (as providers) are not formally recognized or buyers unfamiliar with negotiating directly with farmers (Neef and Thomas 2009). Reliability of the organization and the ability to build trust in schemes are crucial (Koellner et al. 2008, Neef and Thomas 2009). An assessment of the management capacity of seven organizations that sell ecosystem services from tropical forest in Latin America, for example, found that marketing and client satisfaction were often neglected and that different market actors have very different criteria and preferences making it necessary for suppliers to target offers carefully (Koellner et al. 2008). The role of marketing in successful PES activities has not received adequate attention.

Monitoring of policies and projects is important to: detect incomplete or distorted implementation; assess compliance with agreements; evaluate actual impact; and, learn from past to improve future interventions (Lebel and Daniel 2009). Payments must be based on what can be monitored, usually land-use, but in case of carbon sequestration projects more precise accounting is often possible (Wunder et al. 2008b). Sometimes the evidence-base that links land-use to delivery of particular environmental services is weak (Wunder 2007). The typical assumption that "forests" provide the necessary ES is a good example. Another problem is permanence: how to ensure ecosystem services continue to be protected, especially after payments from a particular program or policy end (Wunder et al. 2008b). Donors may be worried about financing long-term projects and how to handle non-compliance given traditional role as aid providers (Wunder et al. 2008a).

Despite some significant limitations, PES and related schemes are an important addition to the set of policy options and instruments to integrate conservation and development. The quality of such schemes ultimately rests on achieving a shared understanding of ecosystems services, benefits and burdens.

Certification

Certification is a practice intended to give a "green" seal of approval to tree plantation or "reforestation" projects and includes chain-of-custody monitoring. One of the foremost timber certifiers is the Forest Stewardship Council, whose members comprise forestry and forestry-related corporations that are part of its "economic chamber". In the 1990s, successful NGO campaigns, particularly regarding unsustainable logging practices in the tropics, led to increased consumer awareness about the consumer's role in forest destruction. When consumers began to ask their suppliers for certified wood, a number of NGOs, together with businesses, decided to promote a process for enabling companies to offer and consumers to choose a "green" product, and resulted in the establishment of the FSC. The FSC allows certifier companies to inspect and then certifies logging and plantation companies who can then sell timber with a FSC certified label.

FSC's certifier companies are active in Southeast Asia and the Mekong region: In 2006, two forest areas in central Laos covering about 50,000 ha in the provinces of Khammouane and Savannakhet, were the first forests in Indochina to achieve FSC certification (WWF 2006). But the independence and credibility of the FSC has increasingly come under question with FSC's failure to prevent the certification of non-compliant companies (Carrere 2006, Butler and Laurance 2008).

Instead of limiting FSC to forest management certification, organizations and businesses participating in the process decided to also include plantation management as part of its mission, lending FSC support to contentious large-scale monocultures that have resulted in severe livelihood impacts on many indigenous and local communities. In the Mekong region, FSC chain of custody has been no guarantee against illegal timber smuggling for instance from Laos to Vietnam.

Information

Increasing public awareness of ecosystem services can help garner wider support for their conservation at level of policies and for improving management practices in watershed areas (Patterson and Coelho 2009). This can be simply at the level of identifying and communicating previously unknown or under-appreciated services, through efforts to value benefits, to integrated assessment of social and ecological impacts and responses (Braumann et al. 2007, Lele 2009).

Opening plans and information to scientific review and consultation is vital to ensure that any relevant policy options are not missed or ignored. This is especially true for instance with fire management where the conventional view of fire is that of a destructive agent requiring immediate suppression. Fire management is crucial for some forest ecosystems to thrive and ensure continued carbon stocks and fluxes (Murdiyarso and Lebel 2007). Fire and disease management can be used to meet land management goals under certain ecological conditions.

Forest management practices for carbon conservation and sequestration range from slowing down deforestation and assisting regeneration in the tropics to afforestation schemes and agro-forestry (Canadell and Raupach 2008). Carbon sequestration can help with climate change protection, but there are many constraints to effective climate-forestry policies. Accidental and deliberate spread of fires into forests can result in huge emissions of CO2 destroying carbon stocks and affecting other watershed services (Murdiyarso and Lebel 2007). The best option for reducing carbon emissions in tropical regions is to avoid deforestation and degradation in the first place (Canadell and Raupach 2008).

The 15th Conference of the Parties in Copenhagen under the United Nations Framework Convention on Climate Change (UNFCCC) agreed to pursue a mechanism for reduced emissions from deforestation and degradation or REDD (UNFCCC 2009). REDD claims to have the potential to benefit developing countries, including swidden cultivators (Mertz 2009), but neglects underlying drivers of deforestation such as logging and tree plantations (whether for bioenergy, oil palm or pulpwood) as well as illegal logging and corruption. Moreover, questions remain whether the funding channels and projects are designed in ways that prevent abuse (Europol 2009) and if the poor actually benefit – an outcome highly contingent on quality of governance within countries.

A formal meta-analysis of studies exploring the watershed services provided by tropical forests and plantations (Locatelli and Vignola 2009) found evidence – contrary to public perceptions and official policies of several countries – for lower base flows under planted forests than non-forest land-uses. It should be emphasized that this evidence comes from studies of only pine and *Eucalyptus* plantations; how plantations with other or native species effects the hydrological cycle is not known. This is consistent with earlier reviews (Calder 2002, Bruijnzeel 2004). At the same time some evidence was also found for lower total flow and higher base flow under natural forests than non-forest land uses when a subset of data from small watershed studies with large differences in forest cover were analysed (Locatelli and Vignola 2009). The authors acknowledge important constraints in a number of available studies of different forest types, and noted that when larger dataset including larger watersheds was analysed no significant differences were found.

Valuation studies have to make many assumptions, but may help convince decision-makers on the needs for conservation of certain land-covers and –uses because of the ecosystem services they provide. Most studies are hopeful about policy impact rather than demonstrating it.

As an example of a typical study Chanhda and colleagues (2009) divided land-use in Luang Namtha province of northern Laos into six classes and derived ecosystem service values for each category based on 11 biomes in a global ecosystem service valuation model (Costanza et al. 1998). On this basis the authors estimated that the forest land cover changes in Luang Namtha Province resulted in a net decline of US$8.9 million in ecosystem services between 1992 and 2002 from potential forests. The decline in the value was due to soil erosion, flooding, drought and other impacts. The authors concluded that the high rate of loss of such services will have serious long-term negative ecological consequences and recommended that land-reclamation projects be controlled and based on rigorous environmental impact analysis that included assessment of impact on the ecosystem services (Chanhda et al. 2009). Use of such indirect estimates for services has many limitations given that values for even an individual service from a particular forest type can vary widely among places (Lele 2009).

A much more detailed and convincing analysis is that done by Pattanayak & Kramer (2001) investigating drought mitigation services of forests in Ruteng Park, Flores, Indonesia. They found evidence that the park provided a drought mitigation service in the form of base-flow to farmers downstream and were able to estimate its value in terms of coffee and rice products. Using scenarios for re-establishment of forests consistent with goals of park management, they were also able to show that further increases in forest cover would result in both increases and decreases in base-flow depending on local conditions and land-uses in different watersheds. From a policy perspective this could help target specific watersheds with the right mixture of climatic and other features where increased protection will yield benefits of this service (Pattanayak and Kramer 2001).

The complexity of landscape changes in many upland watersheds and diversity of services and interests they provide within and beyond the watershed precludes holding much faith in the absolute numerical findings of valuation studies. At least as important as understanding aggregate economic welfare is addressing the question of who wins and who loses under different scenarios of landscape change and why (Lele 2009). Van Beukering and colleagues (2003) note after their valuation of multiple services from Leuser National Park on Sumatra, Indonesia, that although conservation benefits many stakeholders, the "*political power of logging and plantation industries*" means that benefits continue to accrue to just the few stakeholders that favour logging and deforestation. Public awareness building, consultations and negotiations may be critical to secure support for management strategies (Pretty and Smith 2004).

Discussion

Upland watersheds in Southeast Asia provide a diverse range of ecosystem services that are often highly specific to particular land-covers and ecosystems present, the landscape configuration, and social organization. A diverse range of projects, policies and other initiatives have aimed to alter how these services are governed. In this paper we explored these through the lens of plans, rules, incentives and information.

Planning has conventionally been led by government bureaucrats relying on neat physical and institutional separation into conservation and use and instrumentally-driven definitions of classes. Forest and watershed classifications and zoning schemes have been constructed assuming and asserting strong relationships between particular classes and ecosystem services without attention to service users, alternative land-uses or how ecosystem services are actually provided. This has led to unnecessary conflict between state agencies and local communities, disincentives for local conservation actions, and missed opportunities for activities that would maintain ecosystem services and also contribute to poverty alleviation.

Meaningful participation of local resource users alongside the conventional planning done by managers and, more recently, ecosystem experts, should lead to more informed and appropriate land-use plans for upland watersheds that have a chance of being implemented. Deliberative approaches to planning and assessment should help deal with competing knowledge claims about relationships of different land covers and uses with ecosystem services while recognizing that uncertainties of understanding may not be easily reducible. Local engagement is particularly crucial as the benefits of improved watershed management are often localized, and without cooperation and partnerships long-term management goals are hard to pursue (Aylward 2005, Warner 2006).

Regulations important for managing ecosystem services can be top-down, self-generated or more frequently a combination of local, informal, rules and national, formal, regulations (Lebel and Daniel 2009). Interventions where there are multiple ecosystems services and derived benefits invariably create winners and losers. Projects and policies to improve watershed management are undertaken in the context of pre-existing institutions (Mollinga et al. 2007) and as a consequence entail power relations which modify implementation and help shape outcomes. There is therefore a need to strengthen legal support and information sources for disadvantaged groups – like ethnic minorities – in dealing with formal legal processes. We suggest that it is important for future land and forest policies to leave some flexibility for local government and communities to adjust property right systems to local cultural and ecological contexts of upland watersheds. This can take place within a wider framework, for example, that strongly restricts commercial exploitation of certain forest products, but not their subsistence uses.

Incentives can encourage provision of desired ecosystem services and protection of the ecosystems that underlie provision of those functions. Experiences with payments or rewards for ecosystem services is growing in the region suggesting that when used appropriately it will be helpful addition to the set of policy options and instruments to integrate conservation and development in particular places. Outstanding issues include ensuring equitable access, legitimacy of process, and that changes in watershed management actually contribute to well-being of those in most need (Chan et al. 2007, Corbera et al. 2007, Wunder 2008). These challenges are not restricted to instruments like payment or rewards for ecosystem services. A review of 103 ecosystem service projects – from 37 countries – implemented by The Nature Conservancy and the World Wildlife Fund (WWF) looked at projects using traditional conservation tactics such as land purchase and restoration, but also adopting new approaches such as targeting working landscapes, using new financial tools, and involving corporate funding and partners (Tallis et al. 2009). The review showed that all kinds of projects sometimes but often did not meet priority socio-economic needs.

Voluntary approaches are often more flexible than regulations and plans but only work if incentives are adequate or messages and social norms are persuasive enough. Building awareness about ecosystem services is invariably an important part of any intervention, locally or externally led. At the same time many projects and policies have been pursued in absence of detailed understanding of ecosystem functions and services (Carpenter et al. 2009, Daily et al. 2009). Unvalidated assumptions about the relationship between land-covers and hydrological services from watersheds, in particular, abound (Bruijnzeel 2004, Aylward 2005). Much more research on ecosystem services is needed across Southeast Asia, from understanding of ecosystem processes through to benefits and impacts on people. For many watersheds where decisions are being made, significant knowledge uncertainties will remain. Critically drawing on diverse knowledge sources with an expectation that there is a need to negotiate, learn and adapt is the best strategy.

Projects and policies that hope to successfully improve the management of ecosystem services should seek, and expect, to learn from past interventions. Actual management practices in use for timber, water and other ecosystem services from upland watersheds frequently do not match plans on paper; they do not follow agency rules or fit government or other expectations based on simple incentives. Positive changes to ecological sustainability and human well-being are rarely demonstrated directly. In our review, we found monitoring to be the least well developed area of governance: independent and timely post-evaluations of projects and policies are necessary but rare.

There are many reasons including uncertainties in how ecosystems and people will respond to interventions (Berkes 2009), as well as more insidious ones, like systemic abuse, deception and corruption. Institutions need to be flexible enough to update rules to fit new knowledge or emerging conditions rather than assuming the solution is identifying the best practice, land-use or allocation (Lebel et al. 2004). The spread of invasive species, climate change and other larger scale environmental changes with potential impacts on ecosystem services (Chopra et al. 2005) provided by upland watersheds implies that adaptive responses will be imperative.

Conclusions

The upland watersheds of Southeast Asia provide a range of ecosystem services and derived benefits important to the well-being of people within them and beyond. The specific services provided and how they are valued vary hugely from place to place underlying the importance of both ecological and social context. Communities, governments and firms have taken different approaches to negotiating and sharing these benefits, as well as trying to deal with trade-offs between them. In this paper the governance of services was explored through the lenses of plans, rules, incentives and information.

Four broad conclusions emerge. First, multi-stakeholder planning improves the assessment of under-appreciated services and users, but does not eliminate importance of power relations or contestation of knowledge claims by stakeholders with divergent interests. Second efforts to regulate the management of specific or an ambiguous set of ecosystem services with externally imposed rules invariably create winners and losers with outcomes which often depend on pre-existing institutions, political contexts and dominant beliefs about relationships between land-covers and ecosystem services. Third incentives to conserve ecosystem services are closely related to perceived benefits of doing so regardless of whether direct monetary payments are involved or rewards are in other forms. Fourth, shared understanding of the evidence for, and uncertainties around, particular ecosystem process, service and benefit relationships, is crucial to progress, underlying the importance of monitoring and more adaptive approaches to integrating ecological and social understanding.

Taken together these findings underline the need to pay greater attention to issues of governance in the design and implementation of policies and projects to manage ecosystem services from upland watersheds. Improving governance of services is both a technical challenge of improving understanding of ecosystem processes and how they relate to benefits, and a social challenge of ensuring that interventions allocate benefits and burdens fairly while also improving the well-being of vulnerable and marginalized peoples.

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Chapter 4

Managing multiple ecosystem services in the Mae Hae watershed, northern Thailand

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1 Introduction

Upper tributary watersheds in the tropics provide diverse services both to residents and others living further downstream. These include things like water provision and soil renewal for agriculture, non-timber forest products, mitigation of floods, groundwater recharge, soil erosion control, nutrient abatement and carbon sequestration (Tomich *et al.* 2005) (Millennium Ecosystem Assessment 2005).

Governing multiple services, used by different groups and at different spatial levels is a challenge for both governments and communities (Lebel *et al.* 2008; Lebel & Daniel 2009). Communities struggle with issues of heterogeneity, capacity and incentives (Agrawal & Gibson 1999; Agarwal 2001; Berkes 2004; Blaikie 2006). Moreover, the resilience of ecosystems to different uses and management regimes is often uncertain requiring monitoring, learning and adaptive refinement of plans (Lebel *et al.* 2006; Berkes 2009).

In upland areas of northern Thailand farmers living at the rural-forest margin have had to find solutions to watershed management problems to secure their livelihoods and justify their practices to a Thai state that has mostly been highly critical of upland farming (Walker 2004; Forsyth & Walker 2008). State policies have been strongly towards expanding forest cover in upland areas, through the expansion of protected areas and strict controls on land-use elsewhere. Claims about hydrological benefits of forest cover in upland watersheds have been a key discourse of both conservation groups, lowland farmers and public agencies (Walker 2003) though they are rarely based on clear evidence (Forsyth & Walker 2008) and can also be attributed to discriminatory attitudes towards ethnic minorities. Either way, forest and watershed policies have had to confront a reality in which many of the areas in which they are supposed to apply are already inhabited and farmed.

Technological innovations and market opportunities for agricultural products and opportunities for non-farm activities are changing livelihood portfolios of upland farmers (Thomas et al. 2008) and how watershed services are perceived and valued (Neef & Thomas 2009). For example the introduction of PVC pipes and sprinkler or drip irrigation technologies has greatly expanded the places and times in which cultivation is possible (Walker 2003; Badenoch 2006; Neef *et al.* 2006). Towards the end of the dry season in this Monsoonal climate surface flows of water in the mountain streams are greatly reduced and with increasing demand and use may cease altogether. Not surprisingly this has led to conflicts and attempts to improve water management.

This paper explores the efforts of different stakeholders to manage ecosystem services provided by the Mae Hae watershed in northern Thailand. Particular attention is given to the interactions between technological innovations, social institutions and ecosystem conditions. Ultimately our objective is to suggest ways of improving how multiple ecosystem services from upland watersheds are governed.

2 Materials and Methods

We used a mixed methods approach, switching between qualitative and quantitative approaches to data collection and analysis (Mason 2006). Qualitative in-depth interviews, transect walks and mapping exercise in the field with villagers, and engagement in local meetings were central to the investigation of understanding values and use of ecosystem services and efforts at managing them by different stakeholders. Investigation of specific conflicts and problems as they arose or were reflected upon helped understand the role of several key local institutions. Quantitative, household-based surveys were useful for understanding heterogeneity in situations and practices of households within the landscape and differences in perception about key ecosystem service values and trends.

2.1 Study area

Mae Hae watershed formally sits in Mae Chaem district of Chiang Mai province, but as it is right on the border with Samoeng district to the south and Mae Wang district to the east users of water and resources in the watershed can also come from these neighbouring districts (Figure 1). The watershed lies between 18° 46' N to 18° 52' N and 98° 28' E to 98° 34' E and has a total area of about 41km^2. The topography is mountainous with elevations ranging from 1040 to 1760 meters MSL. The main stream is known as *Huai Mae Hae*.

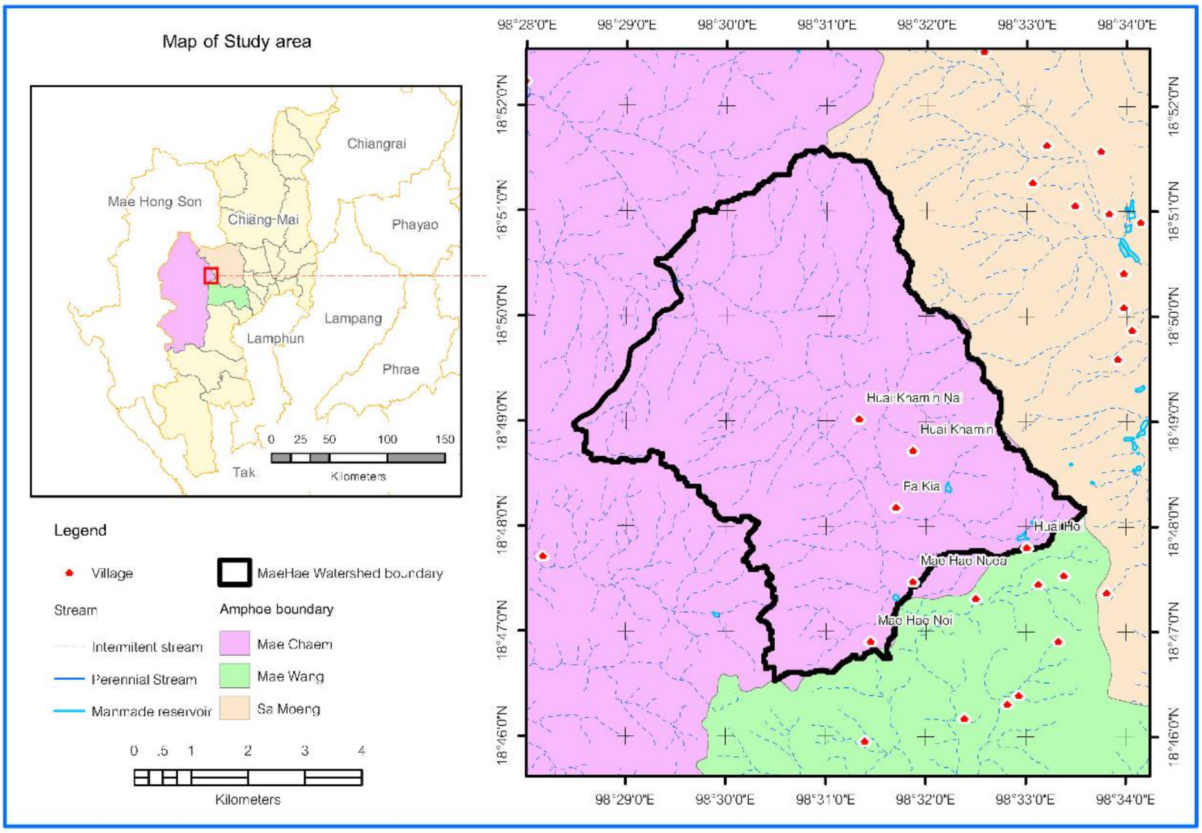


Figure 1 Map of the Mae Watershed in northern Thailand.

2.2 Household survey

A complete list of houses in the 7 administrative villages in the Upper Mae Hae Watershed was constructed. Of 709 household numbers obtained 84 were not current: in 42 cases we could find no trace of a house with that number, and in another 42 cases either house had been removed or if present was not normally occupied. We contacted village headmen to help search for homes in each village. Of the 625 remaining potential households in the sample we were unable to complete questionnaires in 39 instances. In 29 cases we were unable to make appointments and meet the residents that neighbours told us were normally resident despite repeat visits, including in evening or on weekends. This probably included a few individuals who simply did not want to participate. In 10 cases the reason was that household members we met were physically incapable of responding to questions because of age-related disabilities. Complete information was therefore collected from 586 households.

2.3 Interviews with stakeholders

A total of more than 40 in-depth interviews were carried out with various stakeholders involved in management of natural resources in the Mae Hae watershed. Most interviews were taped and fully transcribed and coded using NVIVO software. In a very few instances only interview summaries were available for analysis. Key informants included men and women from ordinary farming households in Karen and Hmong communities, village headmen, local government officials, traditional leaders, officials from the Royal Project Foundation and the Royal Forest Department.

2.4 Land-use and –cover change analysis

Aerial photographs and more recent remote sensing imagery were also analyzed from a variety of sources (Table 1). Aerial photos provided the best source of historical land use for this study. Sequential black-and- white aerial photographs were acquired from RTSD in analogue format at scales ranging from 1:15,000 to 1: 50,000. They were converted into digital form using an A3 scanner. Information about focal length, flying height and fiducial marks were used as important parameters for ortho-rectifying. The scanning resolution of 600 dpi (dot per inch) offered enough information for on-screen digitizing. Ortho-rectification was necessary: (1) to remove len and relief distortions; and (2) to orient to UTM ground coordinate system. Suitable ground control points and a DEM at 30m resolution were used as inputs for ortho-rectification. These procedures were done using ERDAS Imagine V9.1. The final spatial resolution of all ortho-rectified aerial photos was re-sampled to 1 metre, suitable for visual interpretation.

For this study, Landsat MSS and SPOT-5 image were also rectified and co-registered into the digital ortho aerial photographs taken in 2000 to facilitate overlay analysis with the rest of the data. The main objective for using relatively low resolution MSS image (1974) was to compensate missing information (because of cloud cover) from aerial photographs taken in 1972. The rectified SPOT-5 image (2007) at 2.5m resolution provided good spatial information for visual interpretation. The false color composite (321:RGB) was created and enhanced spectrally for digitizing boundaries of different land-use types. Land-use polygons were edited and managed using ArcView V3.3 and ArcGIS V9.1 systems to remove digitizing errors from the data. Land-use polygons were encoded according to the land use classification scheme to obtain 9 LULC types: Paddy rice; Orchard and crop; fallow land, forest, bareland, grassland, villages, water bodies, and miscellaneous (e.g. mines). The rarest classes – bareland, water bodies, villages and miscellaneous – were combined into category “other” for most analyses.

Table 1 Input data types and Sources for land-use change analysis

Dates	Data types	Scale/Resolution	Sources
1952	Aerial photographs	1:50,000	Royal Thai Survey Department (RTSD)
1972	Aerial photographs	1:20,000	RTSD
1983	Aerial photographs	1:40,000	RTSD
1974	Landsat MSS (acquired in January 1974)	57 meters	Tropical Rainforest Information Center, Michigan State University
1993	Aerial photographs	1:15,000	RTSD
2002*	Ortho Aerial photographs	1 meter	Department of Land Development (DLD) Thailand
2007	SPOT-5 image	2.5 meters	GISTDA/via Huaykaew watershed management Unit
1989	Digital Topographic Map (4646I, 4746IV)	1:50,000	RTSD(Use as a reference for locating ground control points from Aerial photography and for field surveys)
	DEM	30 meters	Generated from contour lines

* Use as a reference data for co-registering between other data

The specialist who did the processing of aerial photos and satellite imagery had substantial experience in working in other neighbouring areas in northern Thailand and visited the Mae Hae site with print outs of SPOT 5 image and took photographs to aid with visual interpretation. Oral histories of land-use changes were also an important part of the interviews with stakeholders and for the last decade part of the quantitative household survey findings. These provided additional sources of cross-checking interpretations.

2.5 Observations and engagement

Transect walks were made in several sub-streams to map infrastructure and discuss history and management issues on site. A local representative group acted as guide and informant. Walks were also made around villages to better understand demarcation of different types of forest uses.

Special field visits were made at end of dry season during period where most tensions and conflicts arise. Visits were made to “hot spot” sites to observe and gain more first-hand insight into how communities tried to manage challenges.

We organized three events: one at the level of the watershed network of 15 villages (on 6 September 2008) and two events at the sub-watershed level (27 August 2008; 11 Nov. 2008). The full watershed meeting was part of the regular series of events that villages in the area hold every month. The sub-watershed meetings were convened by the researchers. The purpose of these events was to build space for discussion of water-use and resolve water conflicts; to understand in-depth the problems of water-use; help the community to build water-use regulations; and provide information such as the mapping of water infrastructure such as sprinklers, ponds, and pumps.

3 Land-uses

3.1 Oral histories

Altogether there are 15 villages in watershed mostly Pga-k’nyaw Karen and Hmong people. Local leaders believe the Lua people were present in Mae Hae watershed as long as 800-900 years ago, and that the Karen begun cultivating in the area around 300-400 years ago. The Hmong are known to have first arrived around 70-80 year ago.

The Upper Mae Hae watershed in Chiang Mai province has under gone substantial changes in the last four decades as a result of, successful opium substitution programs led by the Royal Project, and then increasing commercialization of production of temperate crops in the dry season along with expanding conservation objectives of the forestry department. The overall history of changes in land- and water-use can be described in three time periods.

The first period was about 30-50 years with upland swidden farming and poppy cultivation: the inhabitants of MH watershed at that time are ethnic Karen, Hmong, and Haw Chinese. They planted paddy rice, had vegetable gardens, livestock, and gathered non-timber forest products (NTFP) from the forest. The objective of production was for subsistence.

Cultivation was mainly in the wet-season. In the dry season, fields were left fallow. The main use of water for agriculture in that period was the paddy crop of the Karen planted from around May to October that used the *muang fai* weirs to divert and deliver water from the mountain streams. The Hmong cultivated poppy in the wet season from August to January.

Vegetables were planted for local consumption in the swidden fallows and poppy growing and surrounding areas. These included pumpkin, cucumber, bean, taro, chillies, lettuce, cabbage, corn, etc. These vegetables were planted in the upland swidden areas and the poppy growing areas. In the dry-season, people gathered NTFP from forest and from fallow areas such as bananas, ferns, mushrooms, bamboo shoots, etc. were ready for consumption. The swidden and poppy areas therefore produced a variety of vegetables of good quality and fertility was maintained without using chemical fertilizers. Water-use by households was from dug wells and using cut hollow bamboo shafts. In that period, the streams had water all year but in the present period, most of them go dry in the summer season.

The second period, around 25-30 years ago, was the opium eradication and “highland development” period. One of the first projects in Mae Hae was the Royal Project in 1976 and surveyed the village and the needs of villagers and started in 1977. The Royal Project aimed to reduce the poppy and swidden areas and replace with cash crops for market to provide villagers with income and help them survive. But the adaptation of cash crops by villagers was gradual. In 1984-1985 the army came and cleared the poppy growing areas. By 1986, there was no more poppy cultivation in Mae Hae.

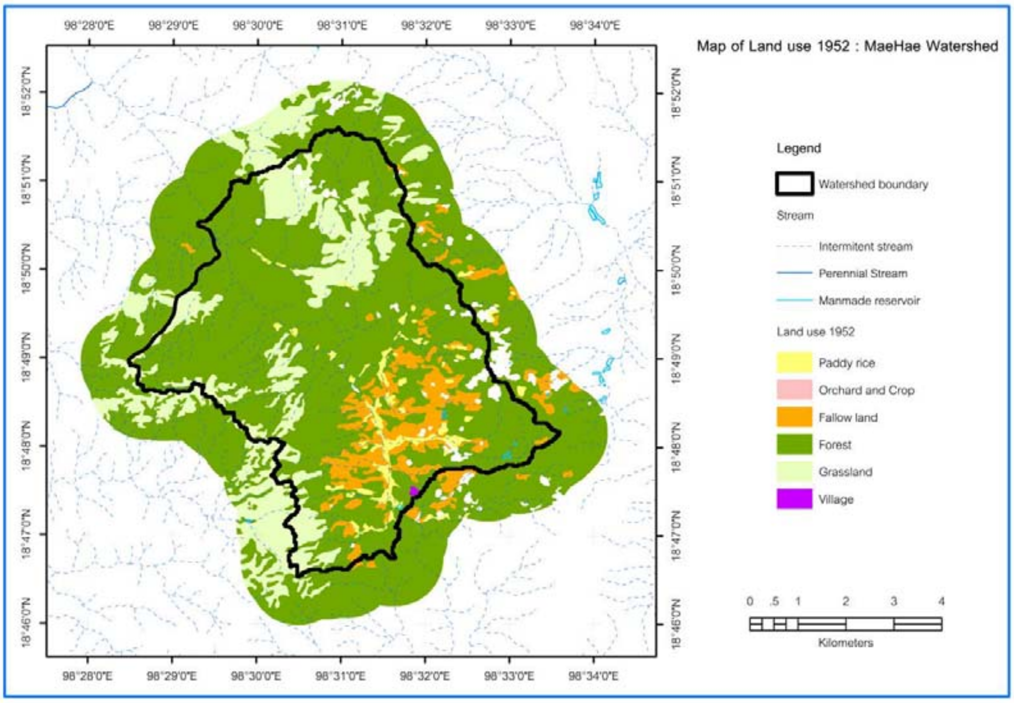
In 1987, state officials began to support the building of village infrastructure eg. building water tanks for domestic water supply, Huay Hoy water reservoir, water tanks in Khun Mae Tian by the Land Development Department (LDD). He RP supported the planting of temperate fruits eg. Chinese pear, plum, persimmon and vegetables such as cabbage, carrot, salads, potato. In the beginning, villagers did not take up the cash crops as they were not sure of the economic benefits compared to poppy cultivation. After a few years, those who planted got income and hence others gradually followed.

The third period, around 20 years ago, began the intensive planting of cash crops and cultivation during the dry-season. At first, most villagers planted vegetables only in the wet season. But after 2-3 years, dry-season cultivation increased. The Hmong were those who first changed to planting vegetables or fruit trees and started planting in the dry-season. They bought rubber pipes to take water from the streams and hoses to irrigate their fields. Soon after they bought PVC pipes and installed sprinklers in their fields to spray water to irrigate their vegetable fields (Figure 2Figure 2). The use of this irrigation technology came partly from the Royal Project and partly from farmers in neighbouring Bor Kaew subdistrict.

Figure 2 Expansion of dry season cash crops was made possible by new water supply and distribution technologies such as PVC pipes and sprinkler systems

3.2 Remote sensing evidence

These major shifts in land-use and livelihoods according to oral histories are consistent with reconstruction of past land-uses from remote sensing imagery (Figure 3A, 3B, 3C). As can be seen from the successive panels parts of the landscape have remained as paddy rice or forest area throughout whereas other parts have changed several times (see also Figure 4). Mae Hae watershed is a heterogeneous and dynamic landscape.



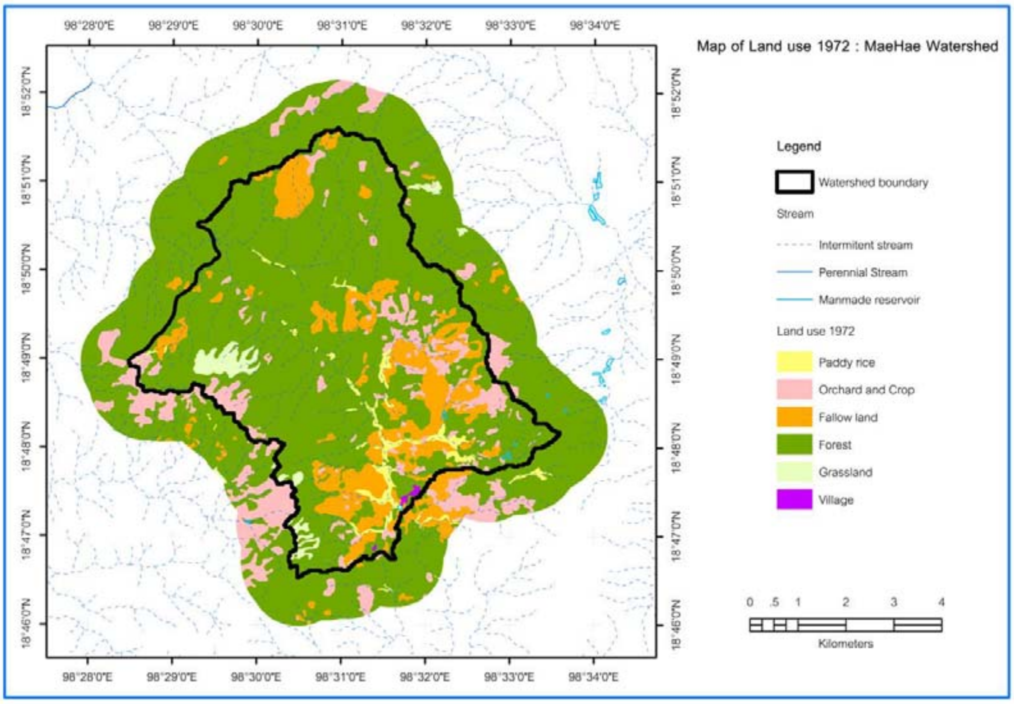
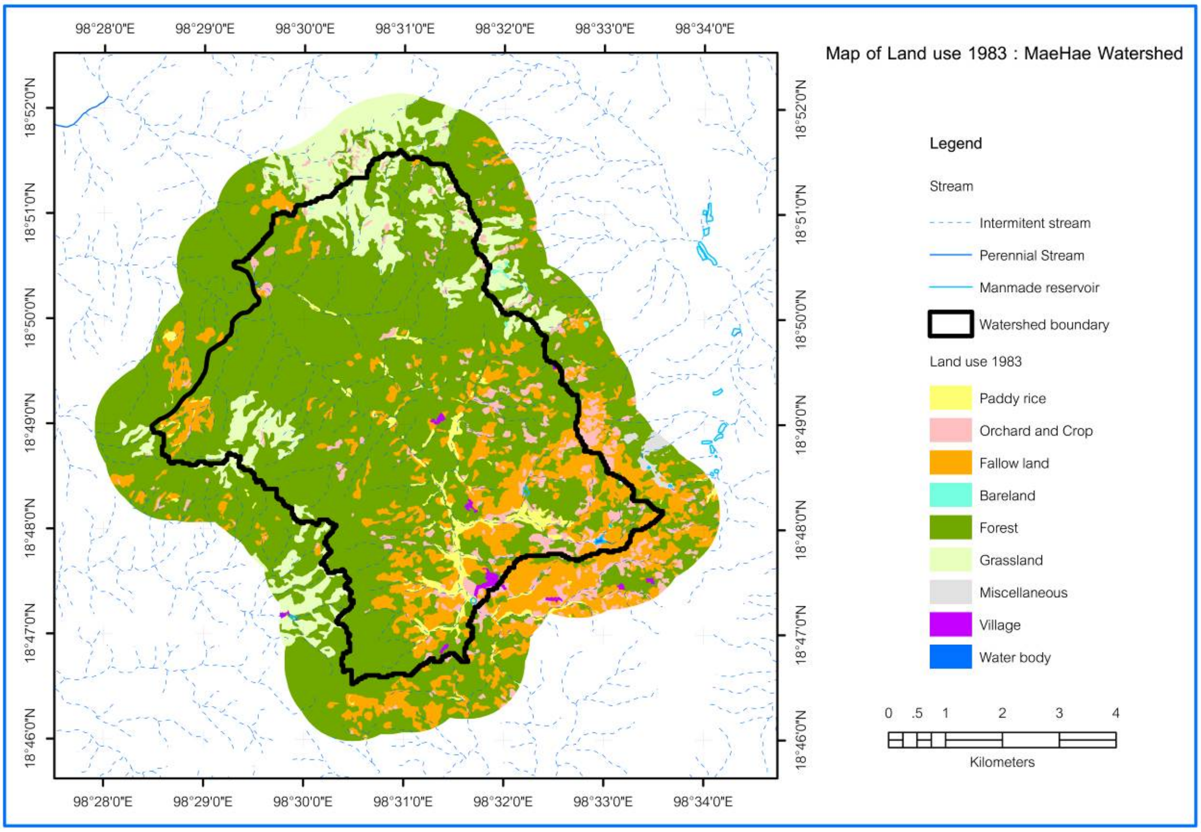


Figure 3A Land-use in the Upper Mae Hae Watershed (1952, 1972).



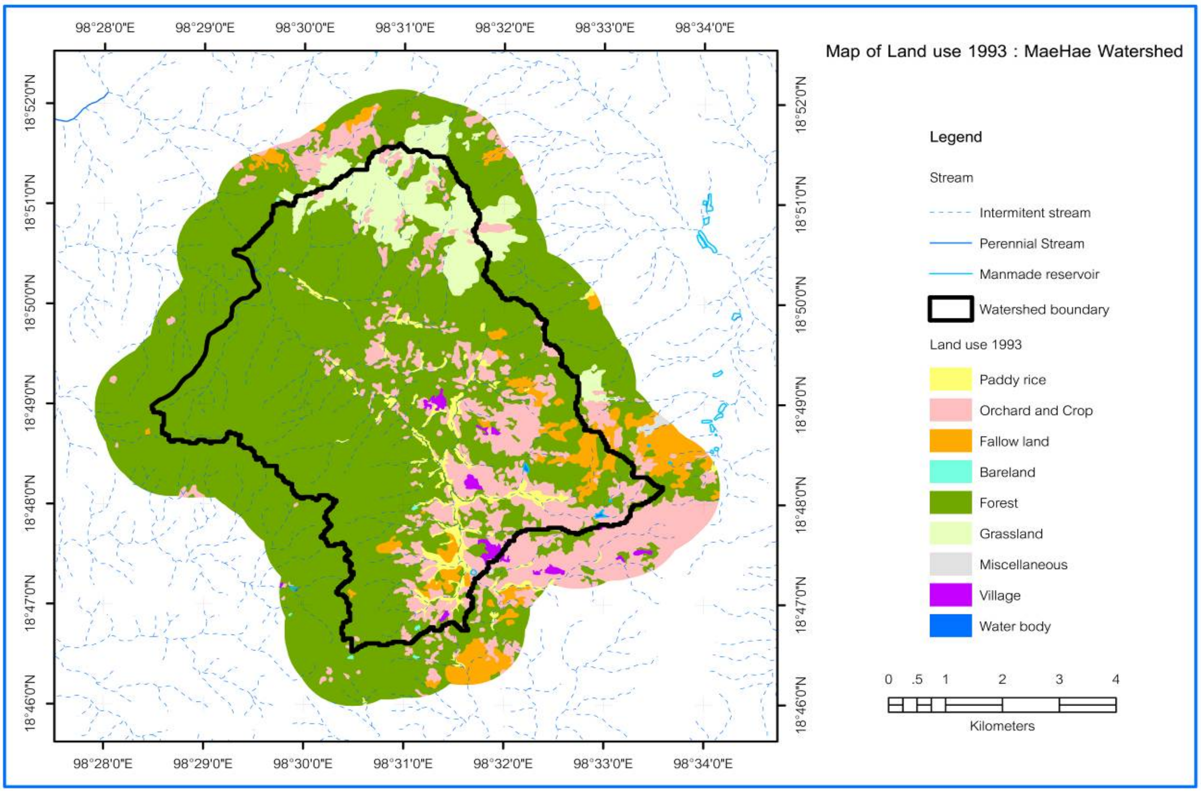
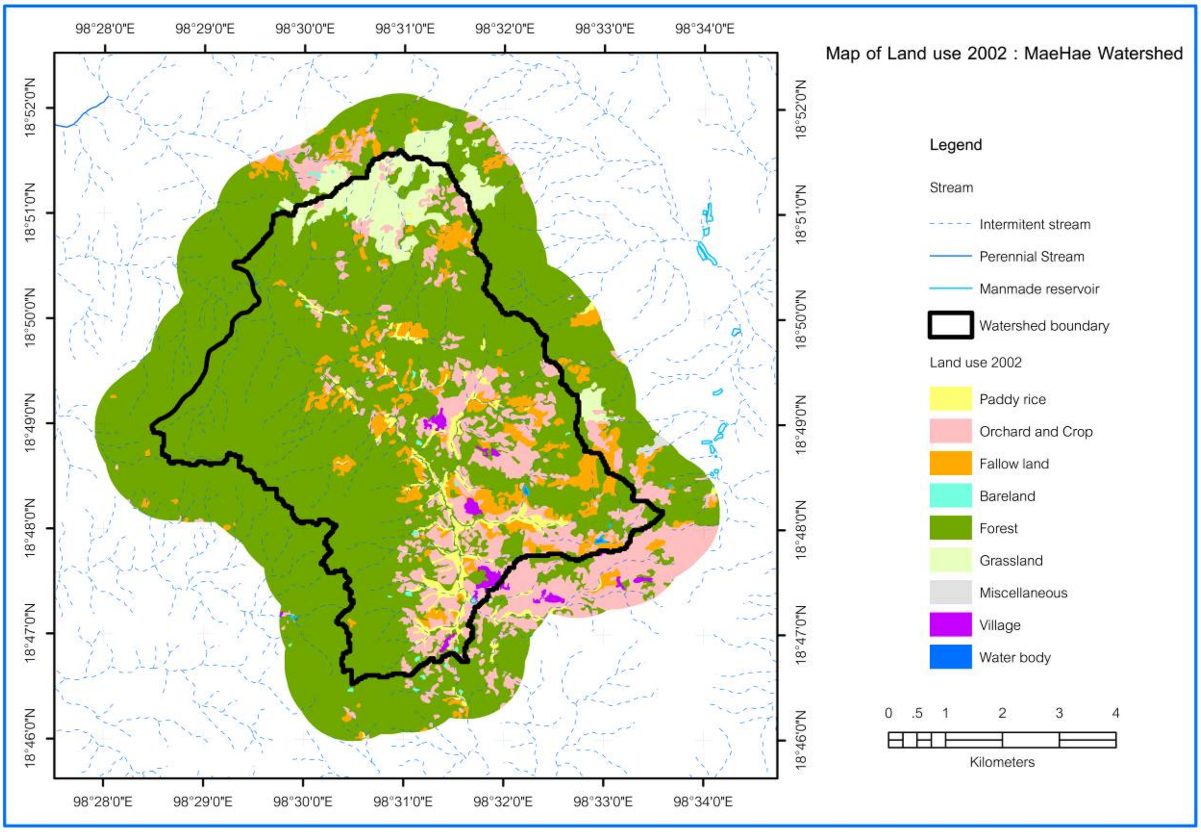


Figure 3B Land-use in the Upper Mae Hae Watershed (1983, 1993).



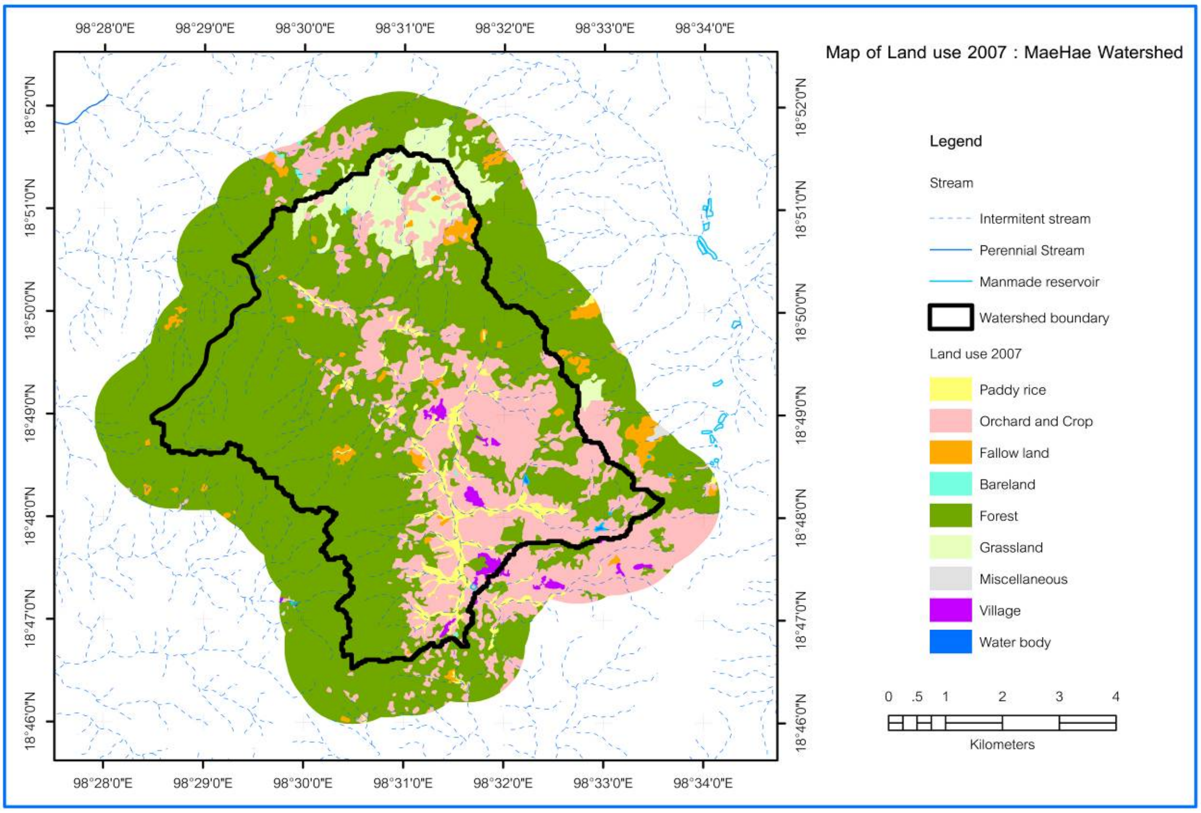


Figure 3C Land-use in the Upper Mae Hae Watershed (2002, 2007).

The dynamics of changes in forest and permanent crops are of particular interest to the analyses in this paper as both these landscape elements provide important ecosystem services and, in the case of agriculture, may also depend on services from other elements of the landscape. Figure 3 shows six snap-shots of forest cover.

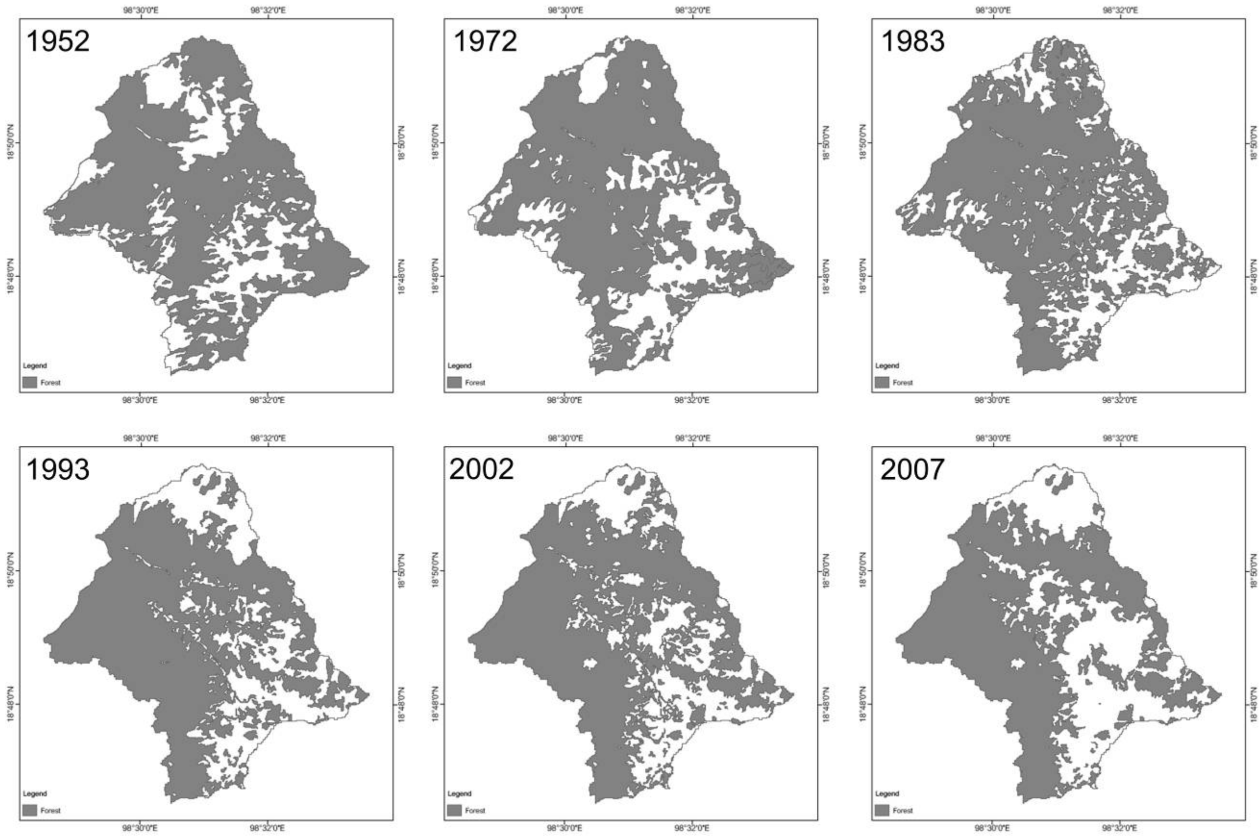


Figure 4 Forest cover at 6 times in Mae Hae watershed (1952-2007)

Almost half (49%) households felt forest cover had declined in their part of the watershed, whereas 12% thought it had increased; the rest felt it had remained more or less the same. The amount of forest products present was judged to have declined by most households (79%) but for a few stayed the same (18%) or increased (3%). Decreases in forest cover were explained by increases in number of households (79%), expansion of fields (77%) and grazing (54%) while increases by forest conservation (67%) efforts.

The perception of residents is in agreement with remote sensing analysis especially data for past 5 and 14 years (Figures 4 & 5). Forest cover peaked in 1983 rising slightly since 1952 but falling thereafter. This is contrary to common perceptions about deforestation in northern Thailand, in particular, that swidden cultivation leads to deforestation of landscapes. As swidden practices declined from a high in the 70's– as implied by relatively high area as fallow – areas under crop and orchard expanded and forest cover fell (Figure 5). Orchards and field crops could not be unambiguously separated from remote sensing imagery in our study site. Some farmers, for example, plant field crops between rows of fruit trees (Figure 6). Areas under permanent paddy cultivation changed only marginally over the 45-year period (Figure 5).

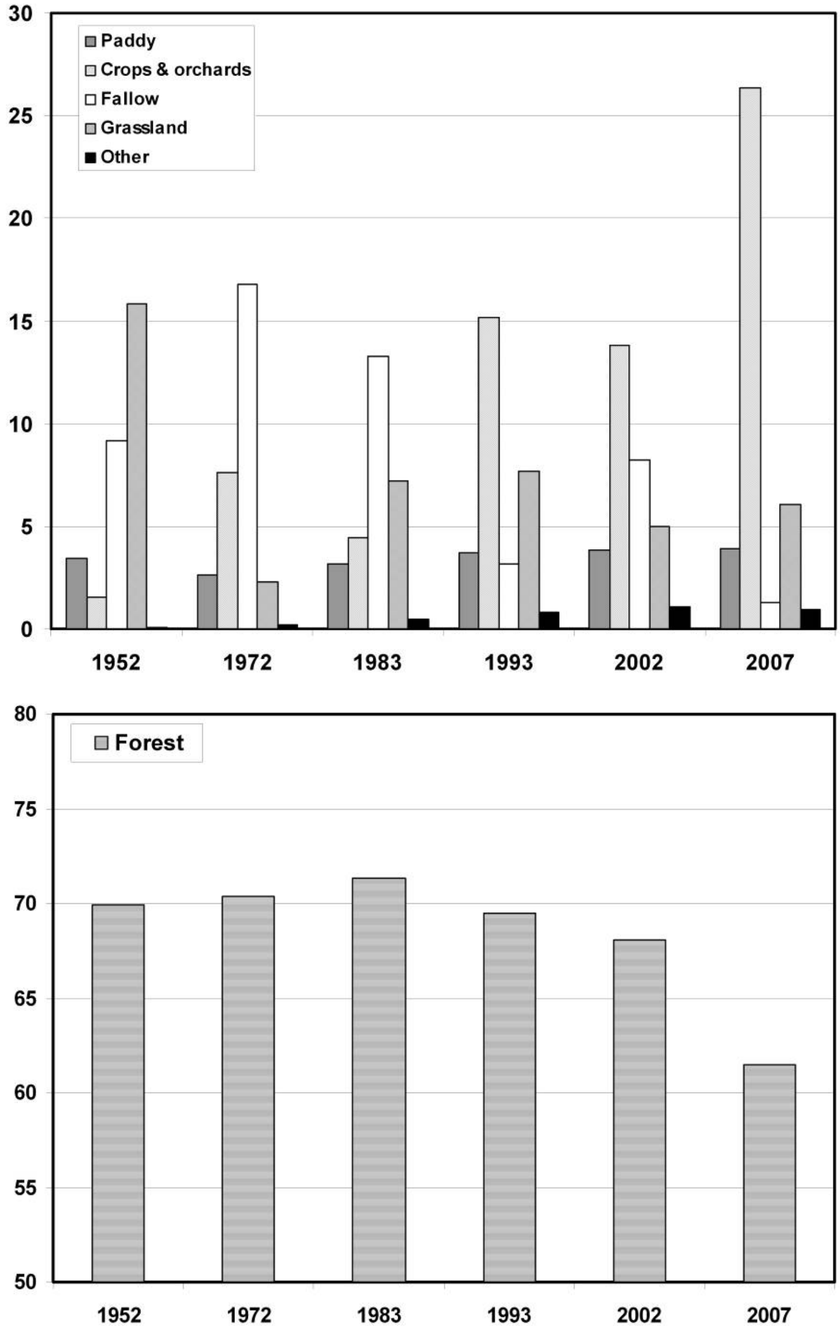


Figure 5 Changes in area as percent of total cover of forests (lower panel) and other main land-uses (upper panel) between 1952-2007. Note differences in scales.

Figure 6 Crops and fruit trees are inter-planted in some fields.

4 Livelihoods

Today, the vast majority of households have agricultural income sources (96%). Half the households had combined average cash incomes of less than 5000 Baht per month (USD 4.7 per day). Mean size of Hmong households (7.49) was substantially larger than Karen households (5.10).

In this strongly seasonal climate there are substantial differences in crops and activities between the wet and dry season. Rice is only grown in the wet season (Figure 7). Two-thirds of households (63%) grew rice and of these only a third (35%) sold any for income. Vegetable growing was more common in the dry (66%) than in the wet (31%).

A third of households (33%) grew rice in upland or swidden fields in the last year. Of these two-thirds (66%) also had orchards and three-quarters vegetable cash crops (75%). Just over half (54%) also had rice paddies. Rice from swidden is usually consumed and occasionally shared with other others. Most of the work on swidden rice fields takes place from the end of dry season through to end of the wet season (Table 2). The median area planted to upland rice was 0.32 ha per household (of those who planted).

Table 2. Percentage of all households working upland rice fields each month.

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Swidden rice	0	2	6	10	30	33	33	33	31	30	11	2

Figure 7 Long-standing local institutions are important for paddy rice cultivation.

Traditionally swidden rice cultivation depends largely on natural ecosystem services and human labor for soil renewal and management. But 30% of households were now cropping every year, that is, had abandoned the fallow cycle completely. Another 26% were halting for 1-2 years and 23% for 3-4 years, and 21% for five or more years. Overall investment in inputs of fertilizer is low, averaging 725 Baht/year and was zero for more than half (57%) of households. Fertilizer use did not vary systematically with fallow length. Agricultural chemical use was rarer (11%) and averaged only 78 Baht/year.

Figure 8 Combination of orchards, swidden fields, permanent crops, secondary forest and forest remnants creates a mosaic landscape.

Half of all households had combined average cash incomes of less than 5000 Baht per month with some variation among sub-districts (Table 3). Karen households are more than three times more likely to be low cash income (<5000 Baht/month) than Hmong households even after adjustment for family size (logistic regression, O.R.=3.04, P<.001). Debt was common in all villages (Table 3).

Table 3. Variation among administrative villages in basic indicators of livelihoods, wealth and water access and conflict histories.

Village	N	Average HH Monthly Income < 5,000 Baht %	Own at least one car or pick-up %	Current debt	History of Water Conflicts %	History of Water Shortages %
Ban Mae Hae	122	58	30	76	7.4	61
Huay Nam Jang	51	28	61	51	3.9	55
Bab Morn Ya	109	32	62	55	8.3	53
Mae Sa Ngad	52	73	29	83	5.8	42
Ban Huay Khamin	118	65	17	75	5.9	66
Mae Tian	91	67	16	79	7.7	42
Huay Hoi	42	14	90	78	17	62
Watershed total	585	52	38	71	7.5	56

Different land-uses draw on different ecosystem services, require different types of labor inputs, and provide different sorts of returns (Table 4). Some activities require a lot of labor inputs during main months like swidden fields, paddy rice and vegetable crops, whereas collection of forest products is much more spread out activity and looking after orchards is primarily time consuming around time of fruiting and harvesting.

Table 4. Comparison of major land-uses.

	Land-use				
	Swidden Rice	**Forest Products**	**Orchards**	**Vegetables**	**Paddy Rice**
Households (%)	32	98	77	77	56
Land area (ha)	0.382	Shared & multi-use	0.972	0.513	0.464
Labour inputs					
Months per year	5.6	*12*	2.4	7.1	5.4
Days per month	14.4	4.8	10.7	21.4	15
People per day	2.6	1.1	2.3	2.7	2.6
Hours per day	7.5	4.6	7.3	7.8	7.6
Hours per year	1572	291	431	3200	1601
Returns					
Product fate	Consumed	Consumed	Sold	Sold	Consumed and Sold

5 Ecosystem services

Most stakeholders held broadly similar views about the importance of forest cover, especially in upper headwater areas for maintaining a variety of ecosystem services. Differences in perception about how such services should be used and managed were wider and will be discussed later under issues of governance (see Section 5). Several specific links between land-cover or land-use and ecosystem services from the Mae Hae watershed were recognized.

In the rest of this section we explore in detail the two services most widely valued by residents – products from forests and water for crops – and then briefly consider evidence about other services to and from watershed forests and fields.

5.1 Water for agricultural activities

Dry season shortages

More than half (56%) of households in Mae Hae usually experienced water shortages in at least one month with shortages most likely between March and May (Table 5). Shortages typically last between a week a month (65%) but occasionally longer (11%). Shortages were most common for field crops (35%) followed by rice (26%) and rare for orchards (3%) or home gardens (0.3%). Shortages are attributed to low flows in the dry season (53%) and less frequently to consumption by others (17%), changes to water delivery systems (2%) or reduced rainfall (2%).

Self reported trends in availability of water a service for agriculture indicate substantial shifts in the past five years with less water being available at end of dry season and more towards the end of the wet season (Table 5). The declines are explained by farmers as due primarily (90%) to less rainfall, but also due to their being more demand, as a result of more households (57%) cultivating more land (59%) with water demanding crops (48%) requiring more infrastructure to extract and store water (41%). The late wet season increases are attributed almost entirely to more rainfall (89%) or greater storage infrastructure (7%) and all other explanations being rare (<3%).

Table 1. Percentage of households (n=585) reporting water shortages as typical in each month and longer-term (5 year) trends in availability of water for agricultural activities in Mae Hae Watershed

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Typically experience shortages	**2**	**6**	**30**	**38**	**23**	**12**	**7**	**2**	**1**	**1**	**1**	**2**
Reduced water availability compared to 5 years ago	**11**	**24**	**71**	**87**	**31**	**6**	**3**	**2**	**1**	**1**	**3**	**10**
Improved water availability compared to 5 years ago	**5**	**3**	**0**	**0**	**8**	**19**	**35**	**70**	**80**	**66**	**21**	**7**

Using logistic regression we explored which households were more likely to face water shortages. There was no significant association with low household income, household size or ethnicity. Households which use sprinklers are twice as likely to face shortages than those which do not use them (O.R.=2.12, P<.001).

Shortages only rarely led to conflicts. Altogether 7.5% of households in Mae Hae acknowledged having ever been in a conflict or dispute with other water users about the allocation, management or use of water. Three-quarters (72%) of these were between water users located upstream-downstream from each other. Conflicts had impacts both on relationships within households (30%) and within wider community (25%). Sometimes disputes affected abilities to grow food (11%), drove changes in technologies (30%), livelihoods (11%) or water sources (11%).

In no instances did respondents say women were more affected by conflicts than men; but in 30% of cases in Mae Hae a men were said to have been more affected. According to both men and women respondents, men (21%) more frequently play an important role in conflict resolution than women (7%). Three households in Mae Hae reported threats as a consequence of water related conflicts.

Conflicts also occur because differences in how rights of access to land and water are interpreted. One way this can happen is after a household moves. Thus a household that now lived in a separate village believed they still had a right to land and water they enjoyed where they use to live. In one case one family fired shots near another's house as a threat. The village heads of Huay Kamin Nai and Huay Nam Chan met to settle the dispute without resorting to police, but appealing to local institutions. In this case the culprits had to go through a public ceremony ("Koh Karma") asking forgiveness by pouring water over the heads of the victims and wrapping their wrists together. The village heads also agreed and emphasized that if there was a recurrence they would report to the police.

Compared to 10 years ago most farmers (74%) said they had same amount of land as before and 13% more and 13% less.

Water was used for a variety of activities. In the last year 56% of households had paddy rice, 77% grew vegetables (after a lowland or upland rice crop), and 77% had orchards. Paddy fields were only irrigated in the wet seasons, whereas many households could be found irrigating fields in any month of the year (Table 6). Orchards were rarely irrigated and only in the wet season.

Table 6. Percentage of households irrigating agricultural fields in each month.

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Paddy Rice	0	+	+	2	48	54	52	52	52	49	13	+
Vegetables	51	51	43	36	43	40	40	40	41	41	52	51
Orchards	+	+	+	+	12	12	12	12	11	10	2	+

Influence of technological innovation

The most important change in farming practices occurred 20-30 years ago when there was a switch from growing crops only in the wet season to year round with vegetables growing in the dry season. At the time many households still continued swidden farming. The technological challenge was supplying water to fields that are away from immediate surfaces sources and separated by complex topography and involved a fairly complex network of infrastructure additions over a couple of decades (Figure 9).

Two small reservoirs were built in Huay Hoi, in 1977 with funds from Japan (R1) and then, in 1983, by the Royal Irrigation Department (Figure 9). The reservoirs were not trusted for the first couple of years by downstream rice farmers, but eventually their usefulness was recognized. A canal made by locals did not work well and were replaced with large steel pipes (10" and 8") supplied by Department of Land Development in 1986 for the second reservoir. Eventually 22 outflows from the main feeder pipes were laid out each servicing 2" PVC pipes (Figure).

Farmers were impressed with the flexibility and efficiency of PVC the pipes that could turn corners and climb over small hills without major losses to the soil during transport. They saw the possibility of delivering water to crops in old swidden field areas not just paddies serviced by traditional Muang-fai schemes.

Today, households got water to their crops via canals, ditches or streams (62%). Three quarters (77%) also used PVC to get water to their crops, mostly depending on gravity, but some also using water pumps (16%). Some PVC supply systems snake uphill for kilometers to actual water source extraction points in stream headwaters (Figure 9). Storage was rare: concrete tanks (1%), earth ponds (1%).

Overhead sprinklers, a key technological innovation, were used by 70% of households in the last year, and are the normal (95%) end of the PVC delivery system. On average households had used sprinklers for 11 years with some starting as long as 25 to 30 years ago. Farmers learnt about sprinklers from other farmers (70%) or the Royal Project (23%). Rates and timing of adoption of sprinkler systems vary by village (Table 7).

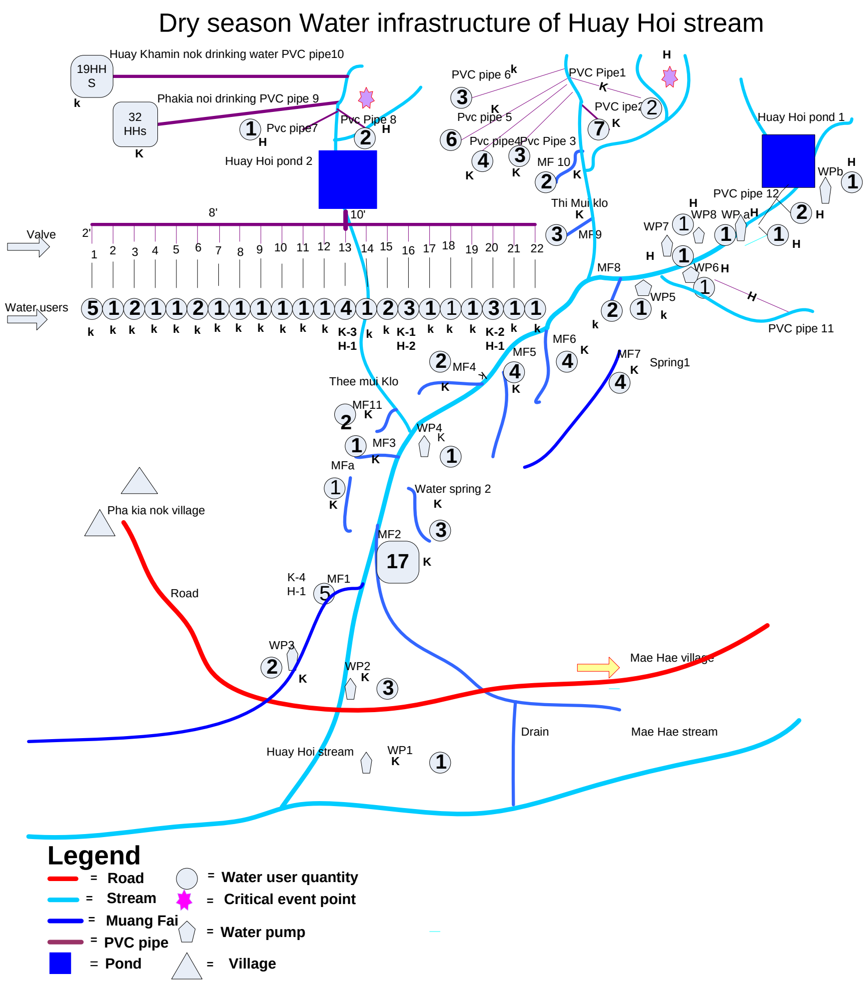


Figure 9. Infrastructure map for Huay Hoi Stream.

Table 7. Adoption of sprinklers in administrative villages

	Sprinkler adoption		
	Never used	< 10 years	>= 10 years
Ban Mae Hae	47	33	21
Huay Nam Jang	16	28	56
Bab Morn Ya	14	24	62
Mae Sa Ngad	66	8	25
Ban Huay Kha Min	22	24	54
Mae Tian	34	39	27
Huay Hoi	9	9	81

Sprinklers are used, on average, for 6.3 months a year, 18 days per month, and 4.8 hours per day. A typical household runs 10 sprinklers each day. A fifth of households (20%) used sprinkler for 11 or 12 months of the year.

Use of sprinklers has increases yields (93%) and profits (85%). They also save time (98%). Few farmers reported problems with the technology. Using sprinklers increased conflicts with other water users (2%) or required negotiation of new water sharing rules (2%). Overall, however, the sprinkler-PVC irrigation systems did not lead to more or less collaboration with other water users (half-farmers thought it did, half did not).

Using logistic regression we explored which households were more likely to have adopted sprinkler technology. There was no significant association with ethnicity. Low income households were less likely (O.R.=0.37) and those with non-agricultural incomes (O.R.=3.31) or many members (>10) were more likely (O.R.=16.8) to have adopted sprinklers.

Another recent innovation has been the introduction of drip irrigation for strawberry fields. This system is left on all day and night, but uses much lower flow rates. There is some debate in the community about whether, overall, it uses more or less efficiently than overhead sprinklers.

Some farmers (16 %) also use pumps. There are several different configurations. Some pumps are individual whereas others are shared by several households. In the latter case costs are shared for purchase and maintenance and there are rules about times when each user use it to supply water to their fields. Some pump directly from streams whereas others take water from ponds. Downstream from reservoir 1 which serves only three families, for example, several households with no access have solved their water shortage problems by digging deep ponds and pumping from these back up to their fields.

Gender and multiple-uses of water

Men and women get water from similar sources and use water for similar activities (Table 8). There was no evidence that indicators of gender relations within a household were associated with the likelihood of a household experiencing water shortages. Indicators tested included: women having bank accounts, a role in borrowing decisions, ownership of land. We adjusted for single-women headed households. Women and men reported similar levels of household water shortages.

Table 8 Uses of water by men and women (% households in which the water source is used).

	Mae Hae		
Water uses	Men	Women	Both
Paddy rice	5	2	93
Other field crops	2	2	96
Fruit orchards	2	2	96
Livestock	2	6	92
Home gardens	2	13	86
Home business	1	3	95
Cleaning house	2	19	80

5.2 Products from forests

Most households collected a range of products from forest areas for domestic use but few to sell (Table 9).

Table 9 Percentage of households (n=585) collecting products from forests in the last year.

Activity	% Households
	For own use (or to sell)
Fuel wood for heating or cooking	97
Wood for construction	56 (4)
Collect plants to eat	83 (1)
Hunt animals to eat	47 (1)
Collect plants for medicinal use	73 (2)
Collect plants for animal fodder	72

Activity	% Households
	For own use (or to sell)
Graze forest land	31
Other forest products to use	22 (0.3)
Forest products for ceremonies	4

There was very little difference between the practices of Hmong and Karen households except with respect to livestock which Karen households graze in forest areas and collect fodder for more often (X^2 tests, $P<0.01$).

There are substantial, if not always absolute differences in collection practices of men and women and between Karen and Hmong communities. Hmong woman are experts in collection and use of forest herbs. Traditional knowledge is passed down among generations. In Karen households men have greater knowledge of forest herbs than women as they have more opportunities to enter forest areas. Karen women are responsible for gathering fuelwood – a good fuel wood pile in a house with a daughter is interpreted as a sign that the women of the household are hard-working and is praised (Figure 10). In Hmong families fuelwood is gathered by men – if they don't it is a sign that men are lazy, but women will collect instead. Men collect timber for building houses and fences.

Figure 10 Fuel wood is an important product from forests

Men and women in both cultures collect wild vegetables from the forest. Hunting of large forest animals is done by men. Men won't eat animals caught by a woman because they say it will bring bad luck to the village. Women it what they catch. Women usually hunt smaller animals like frogs and fish. Food and fodder for chickens and pigs is usually collected by women. Most of these gender differences are not absolute; for most there were significant fraction of households in which both men and women carried out the activity. In in-depth interviews most farmers said that forest products have declined in availability in the last decade because there are more people and land has been cleared.

5.3 Services from fields and forests

Apart from food, fibre and other products obtained from fields and forests a range of other ecosystem services are also provided by the Mae Hae watershed to residents. In table 10 we distinguish between intermediate and final services (e.g. Fisher et al. 2008). Intermediate services include what are often labeled supporting services, but may also include other services depending on the specific benefits being considered. If we increase the scale of beneficiaries considered to outside the immediate watershed then other benefits from ecosystem services become more important and should also be considered like carbon sequestration, tourism and the knowledge useful to science and education. Cultural services are also important locally (Figure 11).

Figure 11 Cultural services are also important. Here a Karen elder places an umbilical cord in a sacred tree

Table 10 Qualitative comparative assessment of ecosystem services from different land-uses in Mae Hae Watershed

	Services from land-use				
	Swidden fields	**Forests**	**Orchards and tree crops**	**Vegetables and other field crops**	**Paddy Rice**
Intermediate services					
Soil formation	++	++	+		
Pollination	+	++	+		
Nutrient cycling	+	++	+		
Wildlife habitat	+	++	+		+
Primary production	++	++	+	+	+
Final services					
Clean-water provision		++			
Food production	++	+	++	++	++
Livestock production	+	+	+		+
Wild foods (mushrooms, fish)	+	++			+
Fuel wood		++			
Cultural and religious	+	++			+
Herbs & medicines	+	++			
Sediment traps and filters	+	++			++
Dry season flows	+ / -	+ / -	+ / -	- -	
Flood attenuation	+	++	+		+
Land area (ha) per household	0.382	Shared & multi-use	0.972	0.513	0.464

Significant uncertainties and controversy exists around the relationship between land-use and several of the most important hydrological services from upland watersheds (Calder 2002; Forsyth & Walker 2008; Lele 2009). First is the issue of how native and planted forests as well as other land-uses affect hydrological flows at different scales. The common perception and claim made by most government officials that forests provide large hydrological services helping maintain dry season base flows and reducing flood risks. These arguments are a major justification for both conservation and re-forestation efforts as well as denying land tenure security to upland farmers. Another common view is that if "*take care of the forest then will have water all year around*". Overall a significant body of scientific research suggests that trees use more water than shorter field crops and thus flows should be reduced in forested catchments and as a result of reforestation efforts but recognize other factors may change the net outcome. Soil conditions, in particular, impact infiltration and are thus affected by management practices (Bruijnzeel 2004). At a monthly meeting of the Watershed Network a representatives from the Watershed Unit emphasized that "*water passes through processes of nature*" before it reaches farmer fields and thus maintenance of headwater forests was especially important. He argued these areas should be re-forested and not converted to cash crops. For the most part the importance of "headwater" forests is asserted and accepted rather than reasoned or demonstrated. Other misconceptions relate to rainfall. A Forest Department official told us, for example, it rains more when there are trees and therefore reforestation is desirable – elevation and orographic effects on rainfall are not widely understood.

Figure 12 Paddy rice fields may act as filters trapping sediments from higher slopes.

The second issue is how different land-uses affect erosion processes and whether or not this results in sedimentation of streams. A common argument is that should "*plant forests so don't lose top soil*", but the same local official recognized can also maintain this service by "*planting grass or wild bananas*" which are also seen as effective at reducing risks of landslides. Some types of tree crops with little leaf cover and compacted soils in between rows may in fact worsen erosion. An important feature of the Mae Hae landscape is the presence of paddy rice fields in the narrow valleys. These are very likely to act as important sediment traps (Figure 12) and indeed their continued productivity may depend on soil replenishment from hillsides. Research on this topic in northern Thailand and other upland areas in Southeast Asia suggests much more attention must be given to roads and paths as sources of sediments to streams, soil and litter management practices and to the filter effects of riparian vegetation and other elements in these complex landscapes (Ziegler et al. 2001; Sidle et al. 2006).

The third issue is the extent to which different land-uses help attenuate flood extremes (Bruijnzeel 2004; Braumann et al. 2007). The most important variable seems to be rainfall – very intense and prolonged events can produce landslips and floods almost regardless of land-uses. Timing is important too – for example, if heavy rainfall events occur when soils are already saturated at the end of prolonged wet season. In other situations infiltration is often the key variable with forests typically having soils with very good infiltration properties whereas in other land-uses infiltration is much more variable. Highly compacted soils may result in overland flow and high peak floods. Overall effects are generally most visible at small scales as at larger scales heterogeneity in land-uses and rainfall results in averaging of impacts on flows.

Given the non-linear trends and complex dynamics of land-use change in Mae Hae over the last 45 years (Figure 3) it is unlikely that there has been major shifts in the hydrological services provided by the landscape to residents or others downstream. A much more significant factor in water provision has been the growth in dry season cropping and hence use of water when water is traditionally scarce. Local institutional developments reflect the needs to manage this valued resource.

6 Watershed governance

6.1 Traditional leaders

8Traditional leaders in the Hmong (Hao Yaw) and Karen (Hee Kho) communities play an important role in negotiations and conflict resolution. Both are invariably male. They have responsibilities for rituals and ceremonies important for management of water, land and forests. Securing water supplies for household consumption and fields are among their key functions, and the high respect in which they are held, means they can be quite effective in resolving conflicts and thus avoid higher level interventions. Traditional leaders interact closely with village headmen, who as a formal leader recognized by the state, deals most with state agencies. The outcome at local levels is a mix of customary rules and state laws with substantial flexibilities in interpretation and use.

In Hmong villages each clan has their own Hao Yaw; the one with the largest clan has higher authority. They are responsible for various animist rituals. The *Fhi Yeng* ritual for instance is to placate the spirits of the place before cultivation or other activities such as digging of ponds . Most Karen villages have Hee Kho, except those which have entirely converted to Christianity. They carry out animist and spiritual ceremonies, many related to farming. For instance, the Hee Kho conducts the *Lue Fai* or the water spirit ceremony for irrigation water-use with every household that takes water from the *muang faai* weir. They also teach with proverbs, songs and stories. The Hee Kho from Huay Khamin Nok village tells people not to fight over natural resources "*because the forest, land and water have spirit-owners. When there is conflict or disrespect for village rules, it affects the entire village. If we have conflicts, the forests and water will disappear*".

6.2 Community-based forest management

For many forest products and activities there are clear rules – mostly spoken – and usually focused on cooperation and persuasion. But there are also some strong taboos, for example among the Karen people, against killing gibbons. Some villages like Ban Mae Hae Noi have clearly delineated conservation and hunting areas are enforce rules strictly. Mae Tieng also clear rules about fishing and collection of other aquatic animals.

Mae Tieng is also active in reforestation programs using seedlings from the Royal Project. State agencies encourage farmers to shift from collecting timber from native forests to growing useful trees on own agricultural land. The need to protect headwater of streams to maintain ecosystem services is a common justification.

Throughout the watershed villages classify their lands although these are not always formally mapped. For example, Ban Mae Nua and Huay Khammin classifications include, apart from agricultural land, collection forest, sacred forest, conservation and headwater forests.

Villagers who need timber to build home must inform a village committee how much they need and where they will cut it from. An official from the Royal Project emphasized to us that subsistence use of timber by villagers was acceptable but they encouraged replanting. Timber is not supposed to be taken from conservation forest. Permission is needed to bring timber from other locations.

Village-level rules are effective because village headmen reinforce them at monthly meetings. If any one is detected breaking rules a village meeting can be called. Warnings are usually issued in first instances. If a rule-breaker comes from another village than an approach is usually made to the head of that village by the headmen. Those we interviewed said villagers had never been fined by external agencies because problems were dealt with internally.

Subsistence uses of small quantities of most non-timber forest products from community or collection forest areas are not subject to quotas or other rules. In some places are rules or advisories like "only collect leaves and not whole plants". If collect to sell then are more rules, for example, like must collect from areas far away from the village.

Aspiration for more systematic management of forests and agricultural lands in the watershed among some local leaders is high. We were told they plan to collect and map information on forest areas and agricultural land in each village so that all stakeholders can work from the same dataset. This will help reduce problems with expanding agricultural land and encroachment on protected forest areas. Communities, they argue, can then develop and enforce their own rules to restrict expansion and will monitor progress every 2-3 years. External agencies would be welcome to be advisors to the process.

6.3 Village and stream-level water management

The rules and regulations in water-use especially for dry-season water management are elaborate and work at different levels. We looked at cases of regulations in practice for particular stream and also for shared use of water among multiple communities.

Most villages have water user committees. Committees consult water users before making major decisions, like raising fees, or changes to rules. Committees help make rules more flexible, for example, by allowing modest compromises on allocations of water: "*As villagers together we cannot be too tough. We need to let problems sort themselves out. Hard a bit, soft a bit, need to adjust as you go. But if it gets out of hand then we must use rules. This is normal for water committees and the strength of participatory management*." (Village head and TAO Official).

The water committee of Mae Hae Nua now organizes meetings, collects water use fees and sets dates and tasks for maintenance of village water supply infrastructure. Water-use regulations of first emerged in 1994 after increased problems with water scarcity in the dry-season. The village pipe water comes from the Saekraejo stream located about 12 km from MHN village. Bringing the water needed investment in materials like pipes and ponds. So the village set up a water-users committee and set up regulations to collect 120 baht/year per household from water-users for the maintenance of pipes, etc. The school in the village pays a higher fee - 1,000 baht per year - since the students and teachers together total 750 persons, equal to the population of MHN. In 1995, the water-users committee found that the expenses for repair and maintenance. were increasing and the water fees collected was not enough for maintenance of water supplies. So the fees were hiked to 15o baht/year for households and 4,000 baht/year for the school. Nine shops in the village pay 200 baht each per year. Three "water caretakers" look after the water levels in the three ponds used for water storage. The caretakers don't need to pay water fees. The caretaker has the duty to open and close the water tap to set timings – the tap is opened from 5 am to 6 pm. If the water level in the storage falls below a certain level, the caretaker must inform the water-users through the village speaker broadcasting system.

Figure 13 Traditional and local government leaders play important roles in management of watersheds, but so do local user groups.

Several villages have strong rules about drinking water supplies, for example, not allowing people to do agriculture or take water upstream from the intake in that stream. We were told that when a family tried to do so despite the ban villagers just removed their pipes and they had to move elsewhere. Some villages have clearer or more widely recognized rules for use of water in the village and from streams for irrigation (Table 10). These correlate with ethnicity.

Altogether about 16% of respondents recognized clear rules for stream water use. Using logistic regression we explored which households were more likely to have recognized rules on use of water from streams for irrigation. There was no association with use of sprinklers, household size, low income, or a history of water shortages. Karen households, however, were much more likely to have or acknowledge rules than Hmong households (O.R.=11.8, P<.001).

Rules typically covered things like: labor to maintain canals (87%), releases of water (54%), bans on dry season water use (34%), bans on diverting water for other purposes or places (34%), restrictions on diameter of extraction pipes (25%), restrictions on times of day water may be used (13%). No villagers admitted to having violated these rules.

The presence of rules are seen to have increased water available for use by half (47%), but a few claimed reductions (6%). Two thirds felt improved stability of supply (67%), and one third (31%) that it reduced water conflicts. Significant rule changes appear to be rare: only 4% indicated they had experienced them.

Table 10. Percentage of households (n=585) in each village recognizing local rules for water use.

Village	Piped water Consumption (%)	Stream water Irrigation (%)
Ban Mae Hae	48	21
Huay Nam Jang	22	0
Bab Morn Ya	18	4
Mae Sa Ngad	14	2
Ban Huay Khamin	45	40
Mae Tian	16	13
Huay Hoi	10	2

There was no evidence that villages with higher levels of water shortage (Table 3) were more or less not more or less institutionalized (r=0.08, P>0.5), that is, had more or less households recognizing rules for using water from streams or canals (Table 10).

Respondents acknowledging water rules (n=91) identified a range of individual and organizational actors which influenced their households water use (Table 11). As noted above the majority of those respondents (84/91) were Karen. We will deal with each of these actors in more detail below.

Table 11. Percentage of Karen and Hmong households acknowledging local rules (n=91) views on influence of different actors on their household's water use.

Actor (institutions)	Influential
He Kho (Karen Traditional Leader)	23
Haw Yaw (Hmong traditional leader)	6

Village headmen	**28**
Water User Group	**36**
Watershed Network	**20**

Different kinds of technologies have their own systems of rules.

Households with access to paddy rice fields, for example, are usually part of communal muang-fai irrigation systems, and typically have very good access to water. Previously they only planted rice in the wet season but now they also planted fast turn-around cash crops like lettuce and zucchini in the dry. Allocation problems are minor, but there are often rules related to labor contributions for maintaining canals.

The feeder lines drawing water from reservoir 2 (Figure 9) has 22 valves. An important rule at the level of the whole system is that there should not be more than 5 sprinklers on per valve at any one time. The rule was introduced in a particularly dry year of 2004. As some people broke the rules and opened valves at night these were fitted with locks. Since then there have been several years with better flows and some farmers have used up to 9 sprinklers at a time without sanction. In 2009 conditions were again dry and the 5 sprinkler rule was fully re-instated along with a time curfew of 0500-2000 (when monitoring was possible). Levels in the reservoir are apparently used to decide when to deploy the 5-sprinkler limit rule. Perhaps the most common rule or norm widely observed is the restriction to PVC pipes with a diameter not more than 2 inches.

Overall 69% of households in Mae Hae belonged to a water user group. Both men and women were often members (Table 12). Committee positions, however, were dominated by men. Both men and women respondents agree that when women participate in meetings about water management – which they only infrequently do (7.5% of households) – they are usually listened to (93%).

Table 12. Gender balance of household representation in water user groups and their committees.

	Mae Hae
Water User Group Member	**(n=403)**
Men	19
Both	78
Women	2
Water User Group Committee	**(n=117)**
Men	91
Both	2
Women	7

There are some institutional gaps at the stream-level and we tried to help some that had been generating persistent low-level conflict. In late 2008 we helped facilitate a meeting convened by a former headmen of 14 representatives from Hmong water-users in the Huay Khamin sub-stream which serves 60 households. At the start of the meeting the history of water-use, management and conflicts in the stream over the last 30 years was discussed. Water-use became much more intensive during the last 20 years with introduction of PVC pipes to divert water from streams to overhead sprinklers. Before Karen residents only did rice farming in the wet season and a few planted vegetables in paddy fields in the dry. Water has decreased in the stream during the last 10 years especially from March to May. Water-users have to carefully plan how much area of cash crops to plant: for example, in the dry-season, farmers can plant only 1-2 rai compared to the wet season of 4-5 rai. Water-use increased again when farmers started planting strawberries three years ago.

We provided maps of current infrastructure based on stream transect walks we had carried out earlier to the meeting as well as summary of our own findings about shortage and conflict histories and institutional responses elsewhere. These inputs were appreciated by participants and contrasted with some past experiences of researchers or officials coming to collect data and disappearing without giving any feedback useful to management.

A local leader argued that conflicts would be reduced if each stream had an appropriately sized reservoir and there were clear regulations for sharing, for instance, all pipes were of uniform diameter and fixed at the same level in the reservoir. This proposal was accepted. The meeting concluded that all 60 families, Karen and Hmong, should meet again to draw up regulations for water use at stream level and cooperate with state agencies to build small reservoirs for storage to supply waters in downstream reaches in the Huay Khamin sub-stream.

6.4 Village heads

The village heads of Mae Hae Nua, Pa Kia Noi, and Huay Hoi have important roles in water management and are all (somewhat unusually) also members of the local water management committees. Village heads cooperate with agencies that come to work in their area: for example, irrigation office of the Royal Project, Watershed Unit Office (RFD), and the international NGO, CARE. They also participate in meetings and liaise with the 15 Village Watershed Network.

Village heads also have a role in helping resolve conflicts within villages, among villages and in the wider network. For example, in conflict over water for Huay Pulawthi stream between Hmong from Huay Hoi and Pa Kia Nai villages resulted in one group smashing new and large (4 inch) irrigation pipes installed by the other village in the land under management of a third village Pa Kia Noi. The three village headmen brought together water users from the three groups and the watershed network representatives. The village headmen of Pa Kia Noi wanted both external groups to leave. In the end, however, a compromise was reached: the new water users were allowed a smaller 2-inch pipe and to take a modest amount of water from a small tributary and not the main stream. The old external users were allowed to stay but not to increase their cropping areas or water use.

In April 2007 within Pa Kia Noi, one household cut electricity to water pumps belonging to another household because (they claimed) they were taking too much water from same stream. The village head inspected the scene and knew that the person who cut the wires had skills as an electrician, and, thus, was also able to infer who did it. The conflict between the two men was close to turning violent, but the village headmen by bringing them together along with their relatives as witnesses was able to diffuse the conflict. He also pushed them to reach a compromise in time, taking turns in different parts of the day, or on different days, to pump water from the stream. He also stressed there should be no further conflicts between the two men.

6.5 Watershed unit and network

The entire Mae Hae watershed area is classified as watershed class 1 A but in 1986 the Royal Project for highland development established a project to promote cash crop farming that covered the 15 villages in Upper Mae Hae watershed thus effectively lifting the land-use restrictions.

In 1999 the Mae Sa Nga Watershed Unit was established by the Forest Department to prevent village encroachment and recover degraded forests in the watershed as well as deal with various state agencies. They formed and financially supported the Mae Hae Network Committee (MHNC) to initiate forest protection activities which included making firebreaks, nurseries for reforestation, building check dams and monitoring forest activities. The committee meets each month.

These monthly forums provide space for village representatives to raise issues and explore shared interests. But the committee often finds that it lacks the necessary authority to resolve water and land-use related problems at both larger, watershed, and smaller, stream, levels. Moreover the Forest Department's objectives in conservation often clash with users interests in access to resources. Finding consensus is difficult.

Meetings of the committee are held at the office of the Royal Project in Mae Hae village. The Royal Project is both a water-user and a water manager in Mae Hae. It works with the 15 villages as well as coordinating with the state and development agencies. It brings in villagers to try and make collective decisions about surveying and finding new water sources, location of farming areas, and resolving and water-use conflicts. For example, the RP built a reservoir near the Huay Pulati stream area together with other agencies such as the TAO, ID, and LDD. The MHNC gains legitimacy through its association with the Mae Sa Nga Watershed Unit.

The network has issued several regulations and indicative fines for offensive. For example, fines of 3000-5000 Baht can be imposed if timber is taken from conservation forest or if timber is brought into a village from elsewhere without permission. Fishing with drugs or electro-shock equipment is also illegal and offenders can be fined. Fines have also been set for burning forest land of 1000 Baht per rai. No fines have so far been issued.

In September 2008 we contributed a facilitated session to the regular meeting of the 15 village Mae Hae Watershed Network. It was attended by 26 persons. The meeting started with regular reports on forest, water and land-use situations in each village and recent activities, for example, related to forest management. The long-term strategy for improving water management of the network included creating opportunities for discussion, negotiation and rule-making. The network has already drawn up some simple regulations, for example, farming is not allowed within 10-20 metres of stream margins in the headwaters.

In the facilitated discussion about management issues and responses the networks' regulations at the high level, however, were challenged as often ineffective or irrelevant to practice. The 10-20m rule, for example, was ignored in many places. Rule-making it was argued needs to be finer-scaled and negotiated with each sub-stream where most of the difficult conflicts have been arising. Mapping of current water infrastructure was viewed as a very useful activity and the network agreed to expand the initial work produced by the researchers to other sub-streams. There was also support for further sub-stream level meetings.

In Mae Hae, more than half (57%) knew of the Mae Hae Watershed network. Of these 86% had been involved in their activities. Forest plantings is one of the main activities promoted by the network and Forestry Department. Most households (89%) both Karen and Hmong had planted forest trees in Mae Hae watershed sometime during the past year. For most (95%) this was for three days or less in the year.

People planted trees for a variety of reasons. Common social reasons were to improve relations with forestry department (71%) and maintain relations with officials or headmen (77%). Payments were an infrequent reason (3%) and most common among those that often planted trees.

Maintaining ecosystem services from the watershed were also prominent reasons given for tree planting: increase supply of forest products (92%); conserve biodiversity and culture (86%); to control flooding (71%).

Figure 14 Forest "ordination". Monks robes around trees to protect them from being cut.

7 Discussion

7.1 Dynamic landscapes and livelihoods

The Mae Hae watershed landscape has been, over large areas, very dynamic over the past four and half decades as composite swidden based farming systems and livelihoods have been steadily replaced with intensified permanent cultivation practices. The expansion of field cropping into the dry season was made possible by technological innovations that have at the same time put a lot of pressure on water-related services from the landscape. At the same time swidden fields have not been entirely given up and remain important for livelihood security. Forests and paddy fields continue to provide important flow of products to households even as they have transformed themselves and integrated into wider market economies around fruit trees and field crops.

The complex patterns in land-use are contrary to official statements of widespread and unidirectional deforestation. Trends in condition of major ecosystems and services provision are probably not as bleak as some officials have claimed. At the same time there is a need to recognize that forests are used and agricultural fields with and without trees provide some level of some valued services important to residents and probably also others downstream.

While many of the services provided by different ecosystems and elements of the landscape to local users are recognized by residents and other stakeholders there are disparate views on their value and the relative merits and needs of different conservation and management practices. The scientific basis for inferring changes in ecosystem services from changes in land-use in these complex landscapes remains modest despite a significant research effort in neighboring catchments, in part, because the relationship are complex and scale-dependent, and in part, because there is a strong politics of knowledge around hydrological services that prevents scientific evidence-based reasoning from being fully used (Forsyth & Walker 2008).

7.2 Governing multiple services

The residents of Mae Hae Watershed have made a significant effort to manage those ecosystem services which are crucial to their livelihood security. Many of the effective actions have taken place at relatively small sub-watershed scales building on existing village-level, cultural or stream-based institutions.

Under pressure, and with guidance from, the Royal Forest Department, through activities of the Mae Sa Nga Watershed Unit, and the Royal Project, appreciation of other, less immediately visible ecosystem services has expanded. In particular there have been some significant efforts in some communities to re-establish more mature forest cover in headwater areas.

The emerging or re-emerging conservation ethic is both pragmatic and strategic. Pragmatic in the sense that forests provide useful products and clean drinking water is a highly valued resource. It is also strategic in that countering the wider public value of upland farmers as forest destroyers is important for the bargaining power of residents in dealing with external agencies (Wanitpradit 2008).

In practice there is a recognition – not always explicitly confronted– by all stakeholders that livelihood security needs must be met and that this requires negotiation, compromise and some trade-offs. Maintaining all possible ecosystem services at some "pre-human" level is not realistic and would be disastrous for residents that aspire to a better life. Access to and use of biodiversity, land and water resources is crucial to livelihoods and well-being.

Improving the governance of multiple ecosystem services from upland watersheds like Mae Hae requires paying more attention to scale, learning or adaptive management, and the fairness and inclusiveness of decision-making processes. There is already a foundation upon which to build in each of these dimensions.

Improving coordination across levels appears to be crucial to dealing with multiple ecosystem services that are associated with upstream-downstream or level-dependent interests.Water in the Upper Mae Hae watershed is governed by multiple institutions that operate around different centres and levels of authority. But not all actions important to decision-making are institutionalized.

Small water user groups, associated with particular stream, reservoir, pump or muang-fai system, are the principal arenas in which water management issues first emerge and are resolved. The incentives to solve problems are immediate and the ability to take action high. Most problems arise towards end of the dry season where the temptations to break rules and regulations are highest, and correspondingly this is when most committees are most active. At the level of the watershed the multi-village network is an arena for planning and strategizing. Abilities of participants to take clear actions are often limited, lying with particular agencies participating or water users.

Individual leaders be it traditional elders, village headmen, or committee members, who have the ability to encourage negotiation, give advice, or work effectively at different levels or in multiple networks play a large role in solving water-use and watershed management problems. Although their main roles are highly institutionalized as key parts of local culture, the new links between formal and informal leaders are much less so, but still very important.

The cooperation between the traditional and formal leaders, in particular, is an important facet in water management in Mae Hae over the past 40 years. Formal leaders focus on developing water resources and follow-up on water-use problems including coordination with related agencies. Traditional leaders focus on rituals and ceremonies but are also involved in resolving issues of water sharing and conflicts together with the headman. The wider network of local leaders acts as a shadow network (c.f. Olsson et al. 2006) of the formal watershed network and includes several shared members.

Socio-ecological systems are dynamic. New problems are responded to with solutions that lead to a new generation of challenges making social learning crucial. The most significant challenge faced by watershed managers has been the expansion of dry season cropping. This has highlighted the importance of natural ecosystems in providing quality water for drinking and crops. Adaptive governance that is sensitive to both ecological and social processes has and will become even more important to dealing with uncertainties and changes.

Institutions important to the management of water in Mae Hae watershed vary hugely in flexibility and to the extent they interact with each other. When a new system of valves and pipes were introduced water users were often able to derive new systems of rules to allocate water when they encountered a longer dry season. The needs to continue allocate provide a huge incentive for flexibility in details of rules.

The most pressing challenges have been those at levels above the small water user groups, like conflicts arising between villages, often of different ethnicity. Here the need for new regulations and The procedures was high and to some extent made both formally by the creation of the watershed-wide network and informally through, in particular, a shadow network of local leaders both traditional and government-sanctioned. Interplay among institutions is an important source of new response capacities even without major changes having to take place in structures of existing arrangements.

At the same time maintaining resilience of the social-ecological system looks challenging. The expanding use of dry season water is a form of "pushing the system to its limits" and does not leave much scope for flexibility apart from seasonal migration to the city if conditions deteriorate or access to water supply for your household promises to be poor. Managing water demand more effectively as opposed to current focus on supply provision could help rebuild resilience of the social-ecological system.

Finally inclusiveness is important to fairness, whether the discriminating variable is ethnic, class or gender. Women, for instance, are major users of water for agriculture in the uplands. Their formal roles in water management decision-making bodies do not reflect their roles and responsibilities. Cultural norms with respect to roles and rights of women among Karen, Hmong and Khon Muang, are different, again adding considerable complexity to efforts to empower women.

7.3 Significance, limitation and future research

The main findings of this study provide further support to observations of institutional flexibility in response to technological innovations observed in a few earlier studies in other watersheds in northern Thailand (Neef *et al.* 2006; Badenoch 2009).

The primary significance of this study is to draw attention to multiplicity of ecosystem services valued and managed and that their governance takes place in context in which aspirations, capacities, institutions, and ecosystems are dynamic and interacting.

One of the main limitations of the current study was that direct measurement of ecosystem services, for example, from different land-uses was not available or attempted. Differences between perceptions and biophysical realities could be substantial and a better understanding could lead to very different management solutions. The impacts of expanding or declining cover of different types of trees on dry season hydrological flows in northern Thailand landscapes similar to Mae Hae remains controversial. The same applies to perceived effects on quality and volumes for drinking water supplies and for sediment erosion and retention processes. Although many arguments are forwarded by stakeholders about the importance of land-uses for various ecosystem services, the foundations of these claims are often weak. Studies that explicitly link evidence about biophysical processes that help maintain valued services with analysis of management interventions and options are needed.

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Chapter 5

Impacts of agricultural land change on biodiversity and ecosystem services in Kahayan watershed, Central Kalimantan

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1. Introduction

Ecosystem services are the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfill human life. They represent the multiple benefits human beings can obtain, either directly or indirectly, from ecosystem functions (Daily, 1967). Many of these are very crucial to human survival (e.g., food and fiber, watershed protection, climate modulation, nutrient cycling, and habitat for plants and animals). Economic valuation of ecosystem services is becoming increasingly important to understand the multiple benefits provided by ecosystems (Guo et al. 2001). A study on socio-economic impacts of plantation projects in Kalimantan, showed that it led to the loss of agricultural land, disappearance of traditional lifestyle and social disturbance within local communities (Potter and Lee 1998).

Land-use change is among the most important factors which significantly affect ecosystem processes and services, since it potentially alters, either positively or negatively, the available net primary production area that is appropriated. But monitoring and projecting the impacts of such land-use changes are difficult because of the large volume of data and interpretation required and the lack of information about the contribution of alternate landscapes to these services. It was predicted that in the future, land-use change is likely to occur predominantly in the tropics, associated with decreases in net primary productivity and warming in surface temperature (DeFries and Bounoua 2004). Land change in the tropics is mainly driven by agricultural expansion and deforestation (DeFries et al. 1999). An example was the convertion of peat swamp forest to the rice field in Central Kalimantan, in 1996. Called the One Million Hectare Mega Rice Project (MRP), it led to the establishment of big canals that resulted in the reduction of water levels in the peat swamp forest, and in the water from the peat swamp forest to Sebangau and Kahayan Rivers. This resulted in decreased primary production and decreased water levels. As such conditions are predisposing to fires, frequent forest fires broke out in Central Kalimantan (Boehm *et al*. 2005), and consequently decreased the biodiversity in the forest and attendant ecosytem services. Now, the MRP is a major fire hotspot region, especially in the dry season (Boehm 2004). There was also a rapid conversion of peat swamp forest primarily into un-used fallow land in 1999 - 2003. If the situation continues, there is a high risk that most of the peat swamp forest resource in Central Kalimantan will be destroyed within few years with grave consequences for the local hydrology, climate, biodiversity and livelihood of the local people (Boehm 2004).

As was mentioned earlier, forest fire is one of the factors of forest degradation in Kalimantan. At the end of the extreme dry season in 1997 (caused by ENSO), the biggest fires broke out over almost all forest types in Kalimantan and Sumatra Island. Forest fires have enormous impacts on the tropical forest ecosystems and biodiversity (Barber and Schweithelm 2000). The estimated extent of spatial damage by fire during 1997-1998 in Kalimantan were 75,000 ha of peat swamp forest, 2,375,000 ha of lowland forest, 2,829,000 ha of agricultural land, 116,000 ha of timber plantation, 55,000 ha of estate crops and 375,000 ha of dry scrub & grass land, in total was 6,500,000 ha (Bapenas 1999). Frequent forest fires occurred during the past ten years, and repeated cycles of burning have completely transformed large tracts of forests into grasslands or scrublands. In a study on the effect of forest fires to biodiversity loss carried out in the mixed dipterocarp forest in East Kalimantan, about 90% of 240 trees in a 1.6-ha permanent plot died due to forest fire (Whitmore 1984).

Reduction in the quality of ecosystem service in the Kahayan watershed was also observed as conversion to rubber plantation consequently leads to soil erosion, sedimentation and decreased water quality in the Kahayan River. Our study site is Bawan Village which is located in the middle stream of Kahayan watershed. Bawan village, is experiencing rapid deforestation and soil degradation. The changing landuse patterns at the cost of ecological services has become an issue of increasing concern. In this context, this study seeks to achieve two objectives: (1) To evaluate the impact of land-use changes to the biodiversity; and (2) to examine how land-use changes affect the ecosystem. We therefore expect this study can offer policy-makers some preliminary recommendations to ensure the sustainable use and management of similar ecosystems.

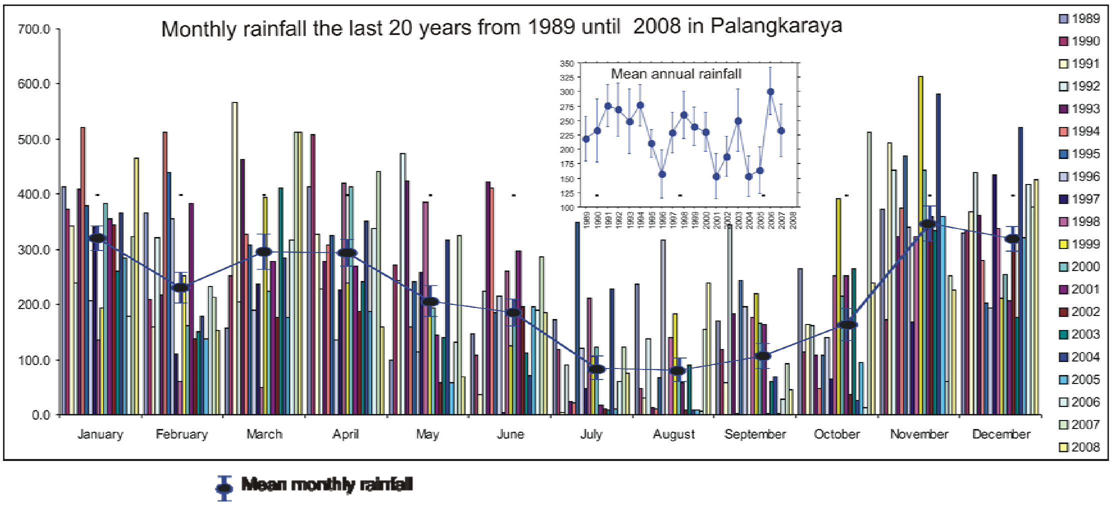
2. Study locations and methods

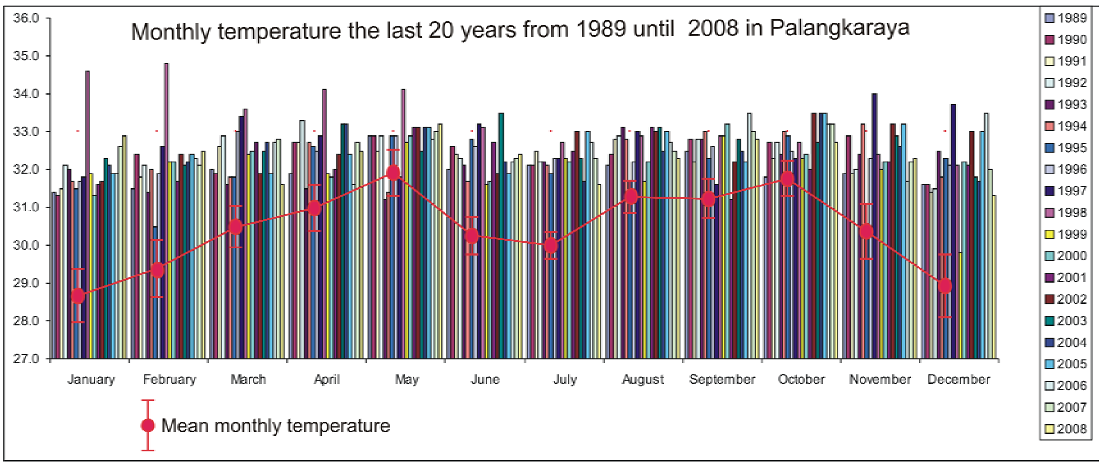
2. 1. Study sites : Bawan Village, Central Kalimantan

Central Kalimantan is the biggest province on the island of Kalimantan, it occupying about 153,800 km^2. It lies between latitude of 0°45 N and 3°30 S, and stretches between longitude 111° to 116°E. Palangkaraya is the capital city of this province, which is located in the upstream regions of Kahayan River. The town occupies an area of about 2,400 km^2. Plantation area covers 3,139,000 hectare of Central Kalimantan including oil palm, rubber, rattan, coffee, cocoa and coconut. Food crops covers area of 5,980,750 hectare including paddy, cassava, pineapples, corns, bananas, rambutan and cempedak (local fruit).

The topography is flat in about 32.97% of the area, hilly area is 9.83% and the area of extreme slope is 40%. Almost four-fifths of Central Kalimantan is made up of tropical forests, producing valuable commodities such as rattan, resin and woods. The biggest river in Central Kalimantan is Kahayan River, which runs from North to South through Kualakulun, and Palangkaraya. The upper stream and downstream is located in Kalukung Mountain and Pulangpisau respectively. The pH of the Kahayan River is around 5.5 – 7.5 in the rainy season, and varies between 4.0 – 7.0 in the dry season. Lower pH during the dry season is due to the strong effects of sulphuric acid discharge from pyrite-containing peat that appears during the rainy season (Haraguchi, 2005). One of the reasons for low water quality is gold mining activity. Some 932 gold mining machines were observed in 2003, and 999 machine in June 2004, from the upper to the downstreams of Kahayan River. Hg (Mercury) content in the Kayahan River was 0.18, 0.39 and 0.23 ppb (part per billoin) in the upper, middle and down stream (Kido et al. 2009). A positive relationship between Hg content in the water or sediment and the number of the mining machines in Kahayan was observed, suggesting that Hg contamination was directly related to the gold mining activities (Yamada et al. 2005).

The annual precipitation in Palangkaraya was 2731 mm (average from 1989 to 2008). Monthly rainfall was in the range of 153.5 - 303.1 mm, and below 100 mm in a few months of the dry season. The annual mean temperature varies between 26.8 - 28.1°C (Figure 1). The lowest annual rainfall was recorded on 1996, 2001 and 2004, while the higest annual temperature was recorded in 1998, a year after the biggest forest fire broke out in Central Kalimantan.





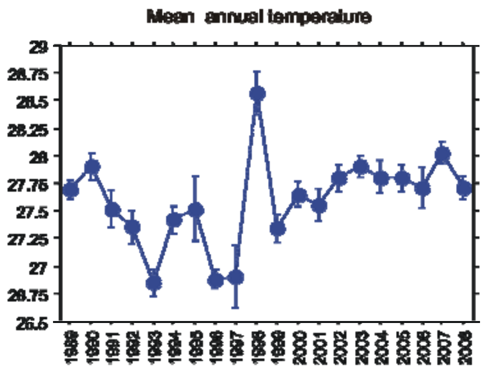


Figure 1 Monthly rainfall and temperature in the last 20 years in Palangkaraya.

Bawan village belongs to the Pulang Pisau District, Banama Tingang sub-district about 86 km from Palangkaraya, and is at an elevation of 25 m above sea level (Fig. 2). Bawan Village is about 87 km^2 in areas. Most of Bawan is covered by the heath forests, with scattered patches of peat swamp forest. Bawan Village is located about 15 m from the Kahayan River bank. The banks of the Kahayan river are mainly covered by rubber plantation (Fig. 2).The number of households in the Bawan village is 211, and the total population is 869. The population in the study area consists mostly of indigenous Dayak groups. About 39% of the respondents were working with the government of Banama Tingang sub-district, 23% undertook farming as their main means of livelihood.

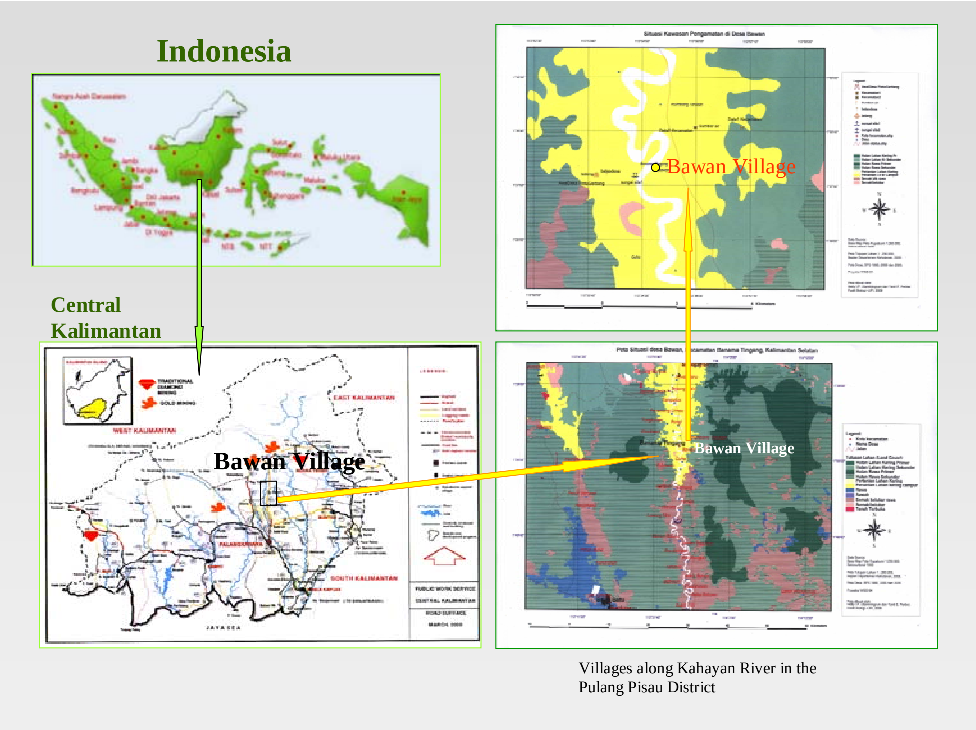


Figure 2 Bawan Village was located in the riverbank of Kahayan River, about 5 - 15 m distance.

The study site for biomass estimation and tree species biodiversity was in the Heath forests. The heath forest in Borneo occur on poor sandy soils, strongly podzolized or even seasonally waterlogged to form humus podzols, humus iron podzols, and ground water humus podzols (Specht and Womersly 1979, Whitmore 1998). In general, the soil in heath forests is very acidic and poor in nitrogen content (Moran *et al.* 2000). Tropical peatlands are one of the largest near-surface reserves of terrestrial organic carbon with 65% or more organic matter content (Mac Kinnon, et al. 1996), they are ombrogenous (rain fed) (Driessen 1978; Morley 1981). The peat deposits are usually at least 50 cm thick, but they can extend up to 20 m. Because peat swamps are not drained by flooding, they are nutrient deficient and acidic (pH usually is less than 4). pH was recorded around 3.4 in the natural peat swamp forest and 3.5 – 4.1 in the agricultural land, while in the rice land was about 3.6 (*Unpublished data*, Rahajoe).

2.2. Participatory Rural Appraisal

Stakeholder meeting and Focus Group Discussion within a PRA (**Participatory** Rural Appraisal) framework were carried out in Palangkaraya and Bawan village respectively in December 2008 and February 2009. The stakeholder meeting was held to identify the current problems of Kahayan watershed vis-a-vis access to ecosystem services by the stakeholders. The stakeholder meeting was attended by participants from various institutions such as: Provincial Center for Environmental Management, Ministry of the Environment, Provincial Center for Watershed Management, The Ministry of Forestry, an Academic from Faculty of Agriculture-Palangka Raya University, Department of Forestry, Department of Mining and Energy, NGO, Marine Affair and Fisheries Department, and elders of the local people (*Dayak*) from the middle to the upstream regions of Kahayan watershed.

The PRA exercise helped to identify the changes to ecosystem services and biodiversity during the last 40 years in Bawan village. The participants were divided into four groups: (1) Mapping of ecosystems group (2) Income and expenditure group, (3) Institution and Infrastucture group and (4) Farming activity group. Based on the information from the PRA exercise, a follow-up survey was conducted among selected respondents in the village based on a structured questionnaire.

3. Results and Discussion

3.1. Current status of Kahayan Watershed

The stakeholder meeting pointed out areas of concern and priority for Kahayan watershed management. The meeting enabled: (a) Bio physical characterisation of Kahayan watershed, including land use, hydrology, soil fertility etc. (b) assessment of the effect of gold mining to the water quality along Kahayan river as well as the effect of land conversion on soil erosion and nutrient depletion, etc. and (c) the need to include traditional knowledge of *Dayak* (local people) for land use planning of Kahayan watershed.

A main concern that was addressed in this meeting was about the zonation of Kahayan watershed. It should be a combination between government and Dayak traditional rule. Other concerns discussed include: (1) Land use overlapping among stakeholders and rule differences in the upstream and downstream area (2) Soil erosion and sedimentation, (3) River as municipal waste reservoir, (4) Illegal gold mining along the river, (5) Water pollution (decrease in water quality) due to the over use of chemical fertilizer, (6) Increase in extent of rubber plantations along the Kahayan watershed, (7) River flow become stronger and (8) Loss of fishing resources. The meeting also led discussions to address Kahayan watershed problems.. These include: (1) Coordination among stakeholders to control and manage Kahayan watershed, (2) Land use regulation of Kahayan watershed based on scientific results, (3) Improve opportunities for employment, (4) Establish Integrated Kahayan Watershed Forum, (5) Increase land rehabilitation every year and (6) Maintenance of the green belt along the river for about 2 – 5 km.

3. 2. Biodiversity and forest Product in Bawan village

Twelve species of timbers and 14 medicinal plants are commonly used by the local people before 1960s. The survey among Bawan villagers revealed 3 major issues (1) Since 2006 only six of timber trees and four medicinal plants were easily found in the forest (Table 1). The population of *Benuas* and *Meranti,* the main timber species during 1960s, decreased. This tendency was also found for medicinal plants (Fig. 3). (2) Decreased pattern of timber production for more than 40 years during the period of 1960 until 2006, due to forest degradation and land conversion to the farming or plantation area (Fig. 4). (3) From 1968 until 1980s, three private forest concessions were in force leading to wood and rattan exploitation. To facilitate accessibility, forest concession companies built a road for transporting forest products to the nearest river, from where they were delivered by boat downstream. This forest concession led to the degradation of the forest ecosystem and consequently affected the livelihoods of the local people. The location of concession company can be seen in Fig. 4A (light green colour). These areas are now used for rubber plantation (Fig. 4B).

Table 1 Major timbers and medicinal plants from the forest.

No	Before 1960	After 2000
I	**Timbers (Local Name)**	
1	Benuas (*Shorea* spp), Dypterocarpaceae	Benuas (*Shorea* spp), Dypterocarpaceae
2	Maranti (*Shorea* spp), Dypterocarpaceae	Maranti (*Shorea* spp), Dypterocarpaceae
3	Krewing (*Cotylelobium Burckii* Heim)	Krewing (*Cotylelobium Burckii* Heim)
4	Pelepek (*Shorea materialis* Ridl.)	Pelepek (*Shorea materialis* Ridl.)
5	Madahirang	Madahirang
6	Kayu tahan	Kayu tahan
7	Ulin (*Eusideroxylon zwageri* T. et. B)	few
8	Ramin (*Gonystilus*)	-
9	Pilau	-
10	Lanan	-
II	**Medichinal plants**	
1	*Eurycoma longifolia* (Pasak Bumi)	*Eurycoma longifolia* (Pasak Bumi)
2	Tabat Barito	Tabat Barito
3	Jaka sembung	-
4	Kelapapa	-
5	Sasenduk	-
6	Saluang belum	Saluang belum
7	Panamar gantung	Panamar gantung
8	Kumis kucing	-
9	Katipei pari	-
10	Akar kuning(*Arcangelisia flava* Merr)	Akar kuning(*Arcangelisia flava* Merr)
11	Memplam	Memplam
12	Tambat bumi	-
13	Tikang siou	-

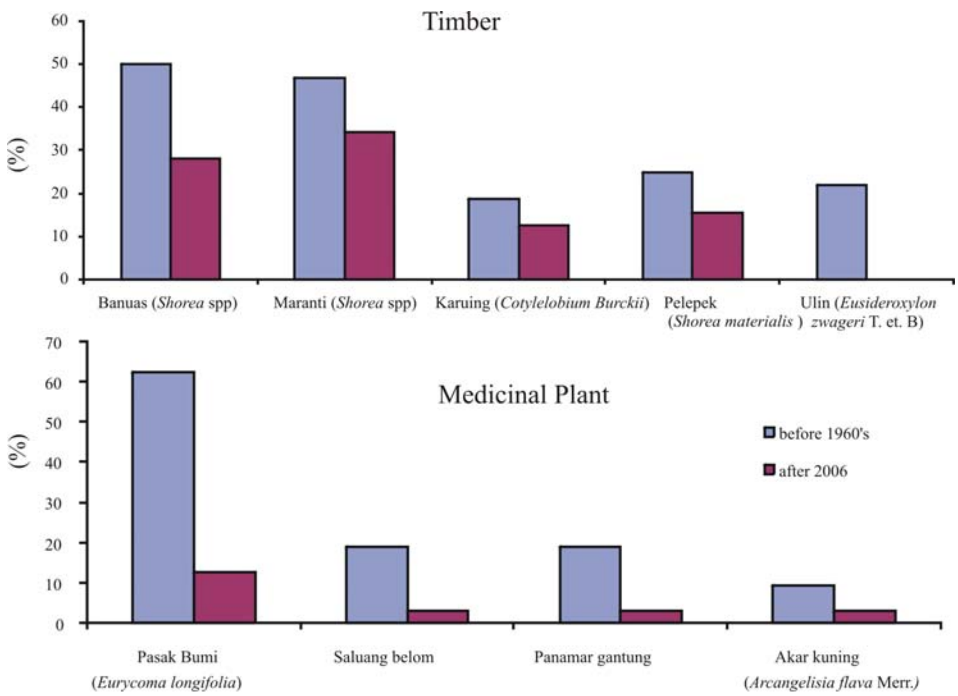


Figure 3 Main timbers and medicinal plants from the forest before 1960's and after 2006

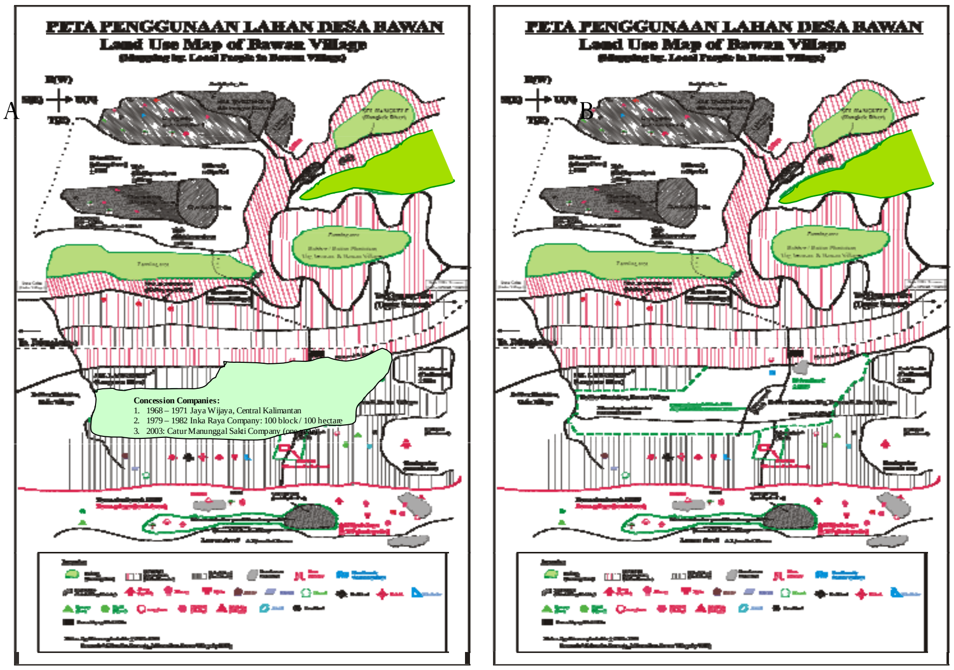


Figure 4 Landuse map of Bawan village (Mapping by Bawan villagers during PRA program)

To establish species diversity in the heath forest, 0.5 hectare permanent plot was established for longterm ecological study in 2009. This permanent plot was located between Bawan and Tumbang Terusan villages. Tree density was about 1224 individuals in one hectare, with a basal area of 25.6 m^2 ha^{-1}. This value was lower compared to the heath forest in Lahei village about 35 km from the study site, whose tree density was 1982 ha^{-1} and basal area was 27.6 m^2 ha^{-1} (Suzuki *et al.* 1998, Miyamoto *et al.* 2002). Forty nine plant species were recorded, belonging to 21 families. Dipterocarpaceae is the major family in this study site, recorded for 12 tree species (Table 2). Important value (IV) of fifteen tree species from the highest to the lowest is shown in the Table 3. The highest IV was recorded for *Calophyllum* cf. *calcicola*. The distribution of tree class diameter was shown in Fig. 5. The trees with the class diameter in the interval of 10 - < 19.9 were recorded for 312 trees. The estimation of biomass production was 147.87 t ha^{-1} and carbon stock was about 78,65 t ha^{-1}. The biomass in this study site was lower compared to that of heath forest in the Lahei Village-232 t ha^{-1} with carbon stock of 127.6 t ha^{-1} (Miyamoto et al. 2007). This information provides an estimate of the potential carbon that would be released from the heath forest, if the forest is converted to plantation and agriculture land in the vicinity of Bawan Village. The differences of above ground biomass and carbon stock in the heath forest relates to the species composition and to the differences in carbon content of each species (Anderson et al. 1983; Moran et al. 2000 & Rahajoe, 2003).

Table 2 Tree species in the heath forest in Bawan village.

No.	Plant Species	Local Name	Family
1	*Gluta renghas* L.	Rangas Manuk	Anacaediaceae
2	*Antidesma Coriaceum* Tul	Pupuh Pelanduk	Euphorbiaceae
3	*Ardisia sanguinolenta* Bl.	Pupuh Pelandok	Myrsinaceae
4	*Baccaurea javanica* (BL) Muell Arg.	Mahui	Euphorbiaceae
5	*Calophyllum* cf. *calcicola* P.F. Stevens	Jinjit	Clusiaceae
6	*Calophyllum gracilipes* Merr	Tampang Gagas	Clusiaceae
7	*Calophyllum lanigerum* Miq.	-	Clusiaceae
8	*Cinnamomum javanicum* Bl.	Sintuk	Lauraceae
9	*Cotylelobium Burckii* (Heim)	Krewing	Dipterocarpaceae
10	*Cratoxylum glaucum* Korth.	Jarunggang	Hyperiaceae
11	*Croton oblongus* Burm.f.	Kepot Bojoko	Euphorbiaceae
12	*Dialium Patens* Backer	Pupuh Palanduk	Fabace
13	*Diospyros curranii* Merr.	Uring Pahe	Ebenaceae
14	*Dipterocarpus elongatus* Korth.	Krewing Bayan	Dipterocarpaceae
15	*Elaeocarpus petiolatus* Wall.	Meranti	Elaeocarpaceae

16	*Elongatus* Korth	Krewing Bayan	Dipterocarpaceae
17	*Garcinia merguensis* Wight.	Enyak Berok Kuning	Clusiaceae
18	*Gluta renghas* L.	Rangas Manuk	Anacardiaceae
19	*Hopea ferruginea* Parij.	Meranti Bunga	Dipterocarpaceae
20	*Horsfieldia irya* (Gaerth.) Warb.	Meranti Kumpang	Myristicaceae
21	*Lithocarpus dasystachys* (Miq.) Red	Ampaning	Fagaceae
22	*Memecylon edule* Roxb.	Banjaris	Melastomataceae
23	*Neoscortechinia kingii* (Hook.f.) Pax.	Parupuk	Euphorbiaceae
24	*Nephelium maingayi* Hiern	Ketiau	Sapindaceae
25	*Payena* cf. *khoomengiana* J T. Pereira.	Nyatu	Sapotaceae
26	*Plectronia glabra* Kurz.	Kayu Tulang	Rubiaceae
27	*Prunus grisea* (C.Muell.) Kalkm	Meranti	Rosaceae
28	*Santiria Laevigata* Bl.	Garunggang, Meranti daun besar	Burseraceae
29	*Shorea Brunnescens* Ashton.	Meranti Batu	Dipterocarpaceae
30	*Shorea materialis* Ridl.	Palepek	Dipterocarpaceae
31	*Shorea rugosa* Heim.	Rasak	Dipterocarpaceae
32	*Shorea scaberriana* Burck.	Rasak	Dipterocarpaceae
33	*Shorea beccariana* Burck.	Mahambung	Dipterocarpaceae
34	*Shorea teysmaniana* Dyer.	Lentang	Dipterocarpaceae
35	*Shorea teysmaniana* Dyer.	Lentang Bitik	Dipterocarpaceae
36	*Sindora leicocarpa* Backer.	Meranti Ehang	Fabaceae
37	*Stemonurus secundiflorus* Bl.	Ehang	Icacinaceae
38	*Syzygium garcinifolium* (King) Merr&Perry	Bangaris, Kapur naga	Myrtaceae
39	*Syzygium* sp 1.	Jambu-jambu	Myrtaceae
40	*Trintaniopsis whiteana* Grift.	Belawan Punai	Myrtaceae
41	*Ternstroemia aneura* Miq.	Ehang, Enyak Berok	Theaceae
42	*Trintaniopsis grandifolia* (Ridl.) PG.Walsen & JT.	Meranti Emang	Myrtaceae

43	*Vatica umbonata* (Hook.f.) Burck.	Ehang Burung	Dipterocarpaceae
44	*Diospyros curranii* Merr.	Uring Pahe	Ebenaceae
45	*Diospyros bantamensis* K& V	Tutup Kebali	Ebenaceae
46	*Pimelodendron griffithianum* (Mull.Arg) Benth	Kayu Gita	Euphorbiaceae
47	*Syzygium zelanicum* (L) D.C	Galam Tikus	Myrtaceae
48	*Syzygium* sp 3.	Kayu Belawan	Myrtaceae

Note: This list was based on the ecological study in the heath forest, which were located between Bawan and Tumbang Terusan Villages.

Table 3 The highest to the lowest Important Value (IV) of fifteen tree species in the heath forest.

Family	**Species**	**Important Value**
Clusiaceae	*Calophyllum* cf. *calcicola* P.F. Stevens	10.585
Icacinaceae	*Stemonurus secundiflorus* Bl.	9.749
Theaceae	*Ternstroemia aneura* Miq.	9.749
Dipterocarpaceae	*Hopea ferruginea* Parij.	8.914
Euphorbiaceae	*Neoscortechinia* kingii (Hook.f.) Pax.	8.914
Euphorbiaceae	*Baccaurea javanica* (BL) Muell Arg.	6.128
Anacardiaceae	*Gluta renghas* L.	5.014
Dipterocarpaceae	*Shorea Brunnescens* Ashton.	5.014
Euphorbiaceae	*Croton oblongus* Burm.f.	4.457
Elaeocarpaceae	*Elaeocarpus petiolatus* Wall.	3.621
Myrtaceae	*Syzygium* sp	3.064
Myrsinaceae	*Ardisia sanguinolenta* Bl.	2.507
Rubiaceae	*Plectronia glabra* Kurz.	2.507
Dipterocarpaceae	*Shorea materialis* Ridl.	1.950
Euphorbiaceae	*Antidesma Coriaceum* Tul	1.393

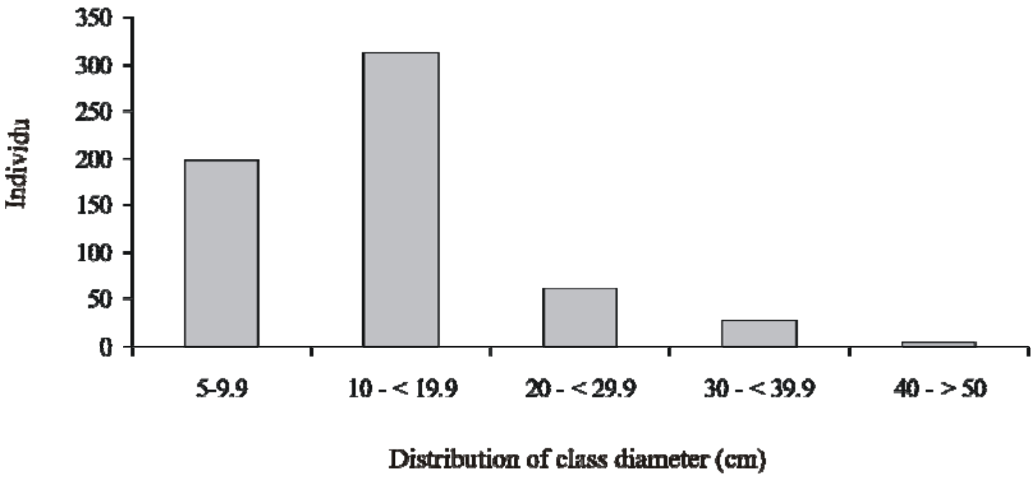


Figure 5 The tree diameter class distribution in the heath forest.

Information from the Bawan villagers helped to easily locate six timber species in the forest, when the results of an ecological study in the area recorded presence of only two species in the heath forest (suggesting a decrease in plant diversity). Other species were found in the peat swamp forest or other locations of the heath forest. This is in line with the decreased pattern of plant species observed by Tyynellä et al. (2003) during the forest conversion program in South Kalimantan.

3.3. Ecosystem services in the Bawan village

During the period 1949- 2009, strong water flow of the river resulted in erosion of the river bank of Bawan village. This led to changes to the Bawan village border, with some Bawan villagers moving their houses to the inland area about 2 - 3 times during the 60 year period. The area along Kahayan watershed, from Bawan village to the other village in the upstream in Gunung Mas Sub district were converted to rubber plantation (Fig. 2 - yellow color indicates the rubber plantation). Illegal gold mining is operated along Kahayan river. There are about 999 gold mining machines from Palangkaraya to Gunung Mas Sub district (Yamada et al. 2005). This resulted in high sedimentation, strong river water flow and poor water quality of Kahayan river. Therefore Bawan villager only used this water for showering the livestock and washing the equipment used for spray insectiside. For household activity, since 1996 they use a spring located about 6 km from the village (Photo 1), in the middle of forest near an eleven year old rubber plantation.

Photo 1 Spring in the Bawan village, where was located about 6 km from the village.

Landscape map of Bawan village drawn by the local people from Bawan, Tumbang Terusan and Goha villages (during the focus group discussions) showed that the forest around Bawan village was covered by the peat swamp and heath forests (Fig. 4). It also illustrated that the villagers still protect the forest for many purposes, such as: sacred site forests, to protect the spring, forest area with high potency of gold mining, and for research and education purposes. The research and education forest was initiated by CIMTROP (Palangkaraya University).

Based on information from Bawan villagers, more than 100 plants species were recorded in the peat swamp and heath forests, while from ecological studies, only 48 tree species in the heath forest were recorded (Table 2). It is predicted that the species diversity increase with increasing permanent plot area. Therefore it is recommended to expand the permanent plot in the peat swamp and the heath forests. In 2000 and 2006 forest fire broke out in the Bawan village and surrounding area following which the area was used for establishing a rubber plantation (Fig. 4). About 1100 hectare new rubber plantations have been established in this location.

3.4. Rubber plantation in Bawan Village

The world's largest producers of natural rubbers are three Asian countries: Thailand, Indonesia and Malaysia. The three countries supply 80% of the world's natural rubber requirement. Rubber is Indonesia’s most important agricultural export commodity, and 75% of national Rubber comes from smallholder’s rubber. In the first half of 2006, Indonesia contributed 2.28 million t to the world's natural rubber exports. Before the 1960s, rubber growers and companies enjoyed good income from high prices. However, the prices have fluctuated in the international market and the price of natural rubber has decreased in the past decade. This also affected the income of Bawan villagers, who have either returned to the forest products for their livelihoods or to cultivate agricultural crops for their daily needs.

The history of rubber plantation in Central Kalimantan began from Dutch colonialism in early 20th century, who introduced Rubber in the region. Before World War I, the rubber latex price was high. Rubber plantation, introduced in Indonesia from 1900 entered South Kalimantan from Pagat near Barabai. By 2004 total rubber plantation area in Central Kalimantan covered 807,254 Ha of which 357,345 Ha (47%) is rubber plantation area, 349,152 Ha of these are local estates (98%) and, the remaining 5,464 Ha (2%) for large estates. Productivity of local rubber was low (500-600 kg Ha^{-1} $year^{-1}$) while that of large estates was 1000-1500 kg Ha^{-1} $year^{-1}$ (http://soborneo.blogspot.com/2006/04/sejarah-pengelolaan-sumber-daya-alam).

Government introduced oil palm plantation program to Bawan villagers. However, they refused the Program to convert the rubber plantations to oil palm plantations due to lack of technology on cultivation of oil palm, and unwillingness to cease rubber tapping, which was a major livelihood activity (Fig. 6 highlights the three major products of the region from 1992 – 2007).

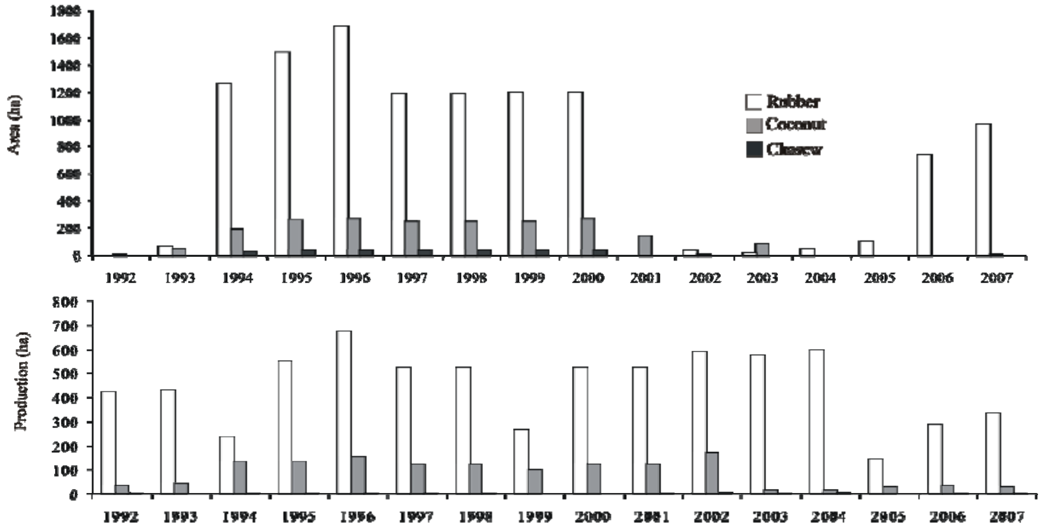


Figure 6 Three major plantation in the Pulang Pisau District from 1992 – 2007.

During the period 2002 – 2007, the area of rubber plantation increased, but the rubber production decreased in the Pulang Pisau District (Fig. 7). This decreased pattern was due to low rubber productivity, resulting from: low fertilizer inputs to rubber plantation, low levels of farmers' technology, poor quality of rubber seeds, non-optimal tree density and most of rubber trees had reached the non-productive age (more than 20 years). The replacement of the old rubber trees is necessary and can be done through several modes including combining local farming culture with planting seasonal food crops. As per custom in the village, rubber tree is combined with rice or other crops (Photos 2 & 3). The integrated tree plantation approach combining indigenous livelihood and industrial wood production is being implemented also in West Kalimantan (Tyynelä et al., 2003).

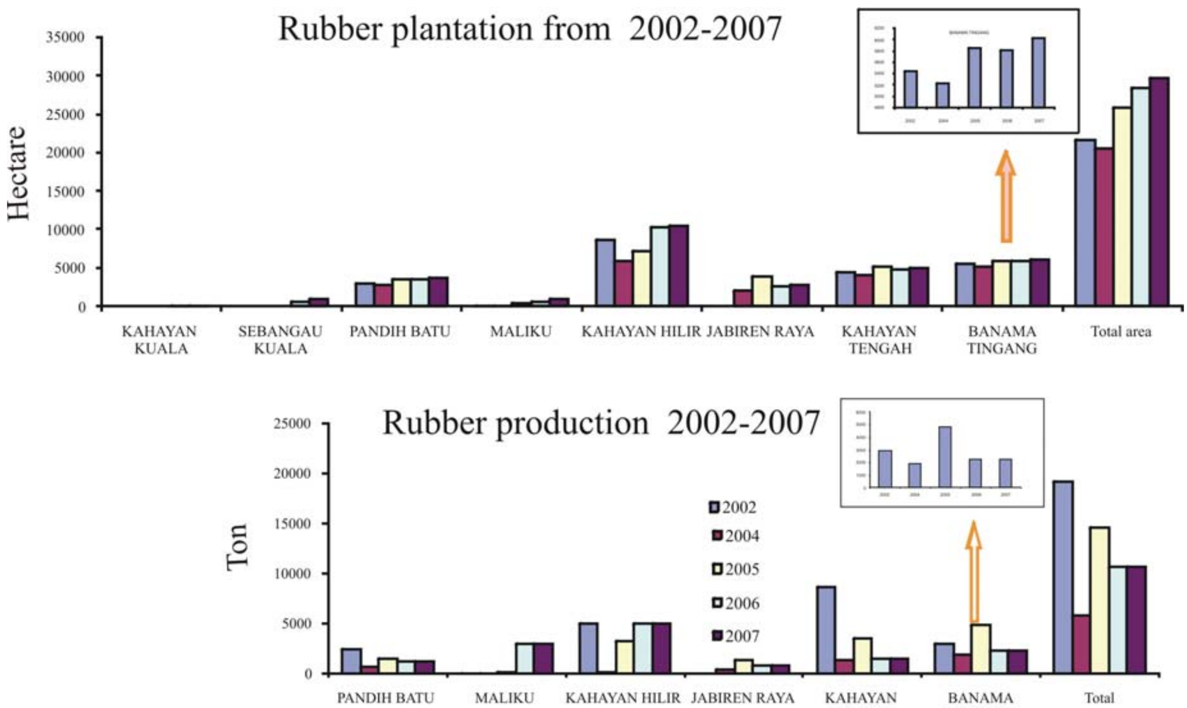


Figure 7 Rubber plantation area and rubber production in the period of 2002 – 2007 in the Pulang Pisau Regency.

Photo 2. Combination between rubber tree plantation (cultivated 2 years ago) and cassava.

Photo 3 Combination between rubber tree plantation (cultivated 1 years ago) and rice.

It is fortunate that rubber could grow in the area with poor soil fertility, such as in the heath forest with the pH of 3.2 to 3.8, N = 0.04 to 0.40%, P_2O_5 = 1.97 to 2.71 mg/100 g, K_2O = 10.2 to 21.2 mg/100 g, Ca^{++} = 0.52 to 1.80, Mg^{++} = 0.22 to 0.28, Na^{+} = 0.17 to 0.28, K^{+} = 0.11 to 0.17 (meq/100 g) (Djuwansyah 2000). This is the best supporting ecosystem to expand the rubber plantation in this area where the main forest type is the heath forest.

Changes in land use for the period 1968 – 2003 in Bawan village is illustrated in Fig. 2. After the government stopped the operation of three concession companies in the region, the local people used the area and areas affected by forest fire for rubber plantations by clear cutting the land. There was no limit on the extent of plantations, which was determined by the muscle power of the person who cleared the land. They could use as much land as they could clear cut. Therefore during the period of 2006 -2008, rubber plantations managed by local people expanded to about 1100 hectares. They received rubber seedlings from government, their own seedlings or from their relatives.

Before the 1980s, the main income of the village, apart from the rubber plantation was from the manufacture of small boats and wooden house rooftops, with supplemental revenue derived from agriculture. Nowadays the main income is from rubber plantation and jobs with the government. Most of the households in the Bawan village have rubber plantations, with an area of about 1- 4 ha. Almost all rubber produced in the Bawan village are sold to middlemen who sell the latex to the traders in Banjarmasin, South Kalimantan. Recently, the rehabilitation and replanting of the rubber plantation increased in the Bawan village, and thus was followed by decreased rubber production (See inset in Fig. 7).

3.5. Changes in farming system and agricultural produce.

From 2002 - 2007, cassava was the main product of Pulang Pisau District, followed by Ipomea (Fig. 8). Peak cassava and ipomea production was recorded in 2004, while groundnut production peaked in 2007. Agricultural products such as: rice, cassava, vegetables and soy beans in the Bawan village are consumed only for their household or personal purposes.

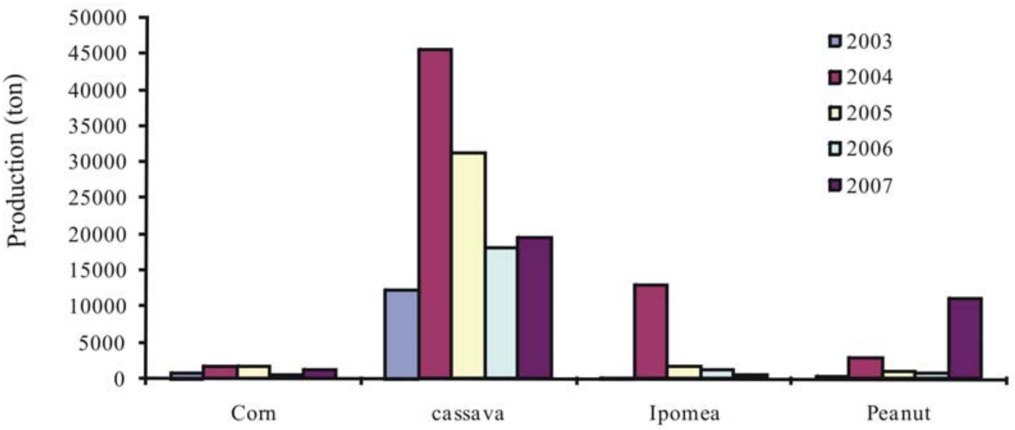


Figure 8 Crops production in the period of 2002 – 2007

Based on the information from the elders, there was a change in the patterns of weather and the flood frequency in their village over the time period. Before 1960's, the weather was predictable. Flooding frequency increased in the rice field, from once to three or four times a year. This results in failed harvest and reduced rice production.

In Bawan village, the farmers used to cultivate rice in September during the rainy season, using local rice varieties (Siung rice, pelita rice or amuntai rice). Siung rice is adaptable to the highland/ upland area and amuntai rice grows in the lowlands under waterlogged conditions.. Harvest time is in April or May, depending on the weather. But today, as it is difficult to predict the weather, cultivation time has to be frequently changed. Some farmer narrated how soon after they sowed the rice, the rice field was flooded forcing them to recultivate. This increases the cost of rice cultivation cost and sometimes results in crop failure.

In the 1960s the farmer needed 4-6 cans (1 cans = 10 kg) of seeds to cultivate rice in one hectare, and the rice production was about 200 cans. But today, the rice production is only about 50 cans, because of unpredictable weather. Bawan villager faces many problems to cultivate rice, such as: the river water rises up and flows to the lowland rice field, submerging the crop. The flood frequency is reported to have increased after 2000. to four until eight times a year, from being only once a year. Therefore, it has become almost impossible to cultivate the rice in the lowland. Cultivation in the highland is hampered by limited water for rice growth during the dry season. This resulted in a reduction in lowland rice area and an increase in upland rice area in the Pulang Pisau Regency (Fig. 9). Decreased pattern of rice in lowland area and decreased total rice production during 5 years period from 2002 – 2007 is illustrated in Fig. 10. The pattern is the opposite for upland rice, which showed an increase in area and increased rice production. This indicates that there is a changing pattern from lowland rice to the upland rice, and conversion of farming area to plantation lands (Fig. 7), that is corroborated by the data in the Fig. 2 (the yellow area along Kahayan watershed is plantation area). Due to decreasing rice production in the village, since 5 years ago the villagers started to purchase rice for daily consumption to supplement the supply from their rice production.

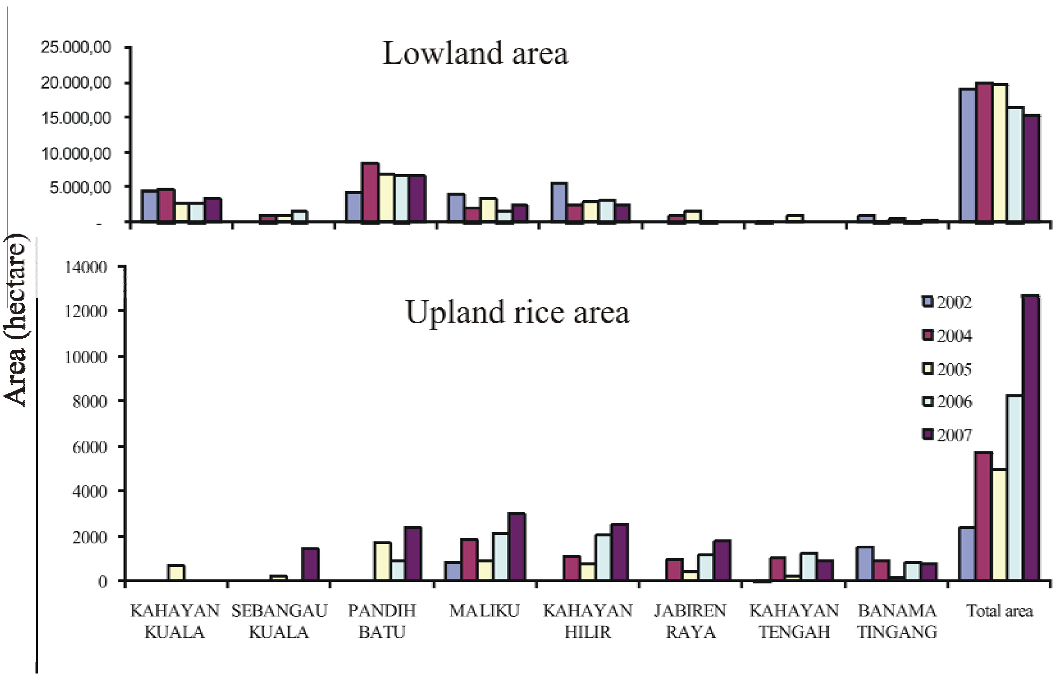


Figure 9 Lowland and upland rice area in the period of 2002 – 2007 in Pulang Pisau Regency.

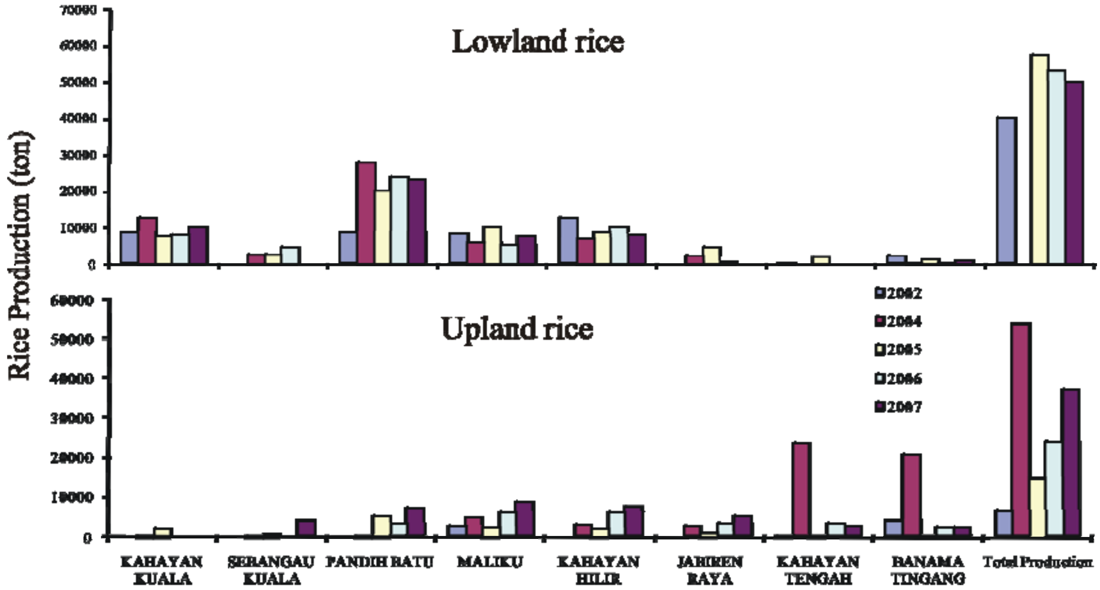


Figure 10 Lowland and upland rice production in the period of 2002 – 2007 in Pulang Pisau Regency.

4. Conclusion

The impact of changes in agricultural land use to the biodiversity and ecosystem services was described in the Bawan Village. Unpredictable weather during the 40 year period has led to failure of rice cultivation and products (thereby affecting food security), increased flood frequency in their village, change of water source from Kahayan River to a spring and decrease in plant diversity and products from the forest. One hectare heath forest conversion results in about 73.78 t ha^{-1} carbon release from the above ground biomass. This reflects enormous carbon sequestration potential from land use systems that conserve forest. There is a need to develop such land use systems that not only benefits the environment, but also improves the livelihood of the local community.

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Chapter 6

A Study on Management of Ecosystem Services in Supa Watershed in Yunnan Province of China

Xing Lu, Zhaohui Yang and Wanying Wang

1. Introduction

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits. [20] In recent years, as the global environmental problem is becoming prominent, ecosystem is facing a deeper pressure day by day, thus study on the ecosystem service function has already attracted extensive attention. Moreover, it becomes present forward subject and hot issue in ecology and ecological economics research.

In 1970, SCEP (Study of Critical Environmental Problems) has proposed the service function of ecosystem. Since then, after constant supplement and evolution, ecosystem service function is generally acknowledged and used as a scientific term and becomes an important branch of ecology and ecological economics research. At present, in the western academia, the research on ecosystem service function has already been launched extensively. From different research angles, some scholars carrying on research in terms of different disciplines such as ecology, economics, some focusing on technology and method of ecological service economic value assessment, and some paying attention to ecological service mechanism and interaction of bio-diversity etc. Millennium-ecosystem Assessment (MA) launches the overall concern to the ecological system service and a lot of case study worldwide. Moreover, ecosystem service function categorized system it put forward has got the extensive recognition in the world. [21] In China, since the middle 1990s, the study on ecological service system has been developed gradually. Based on the foreign research, Chinese scholars have carried on the positive discussion on the global, regional, urban and mono-ecosystem (mainly on forest ecosystem), single-specie ecological service system as well as assessment theory and method on its value.

With constant deepgoing and enlargement to the study, some problems and contradictions begin to appear as well. For example, “the beneficiary pays” is the main adoption in ecological compensation at present, but it is the externality or public beneficiary pays that is mostly discussed in China. Meanwhile, benefited colony in the watershed is seldom paid close attention to, so is the internality. This text takes Supa watershed as an example, MA frame as the theoretical foundation, literature data, satellite image and field investigation etc. as research approaches, starting with internal character of ecosystem service function, focusing on the benefit of ecosystem administrators and protectors. In this way this study can achieve the goal of discerning the ecosystem service value and all beneficiaries, analyzing the existing management mechanism and different beneficiaries' view, and discussing feasible ecological compensation scheme.

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[20] MA, *Ecosystems and Human Well-being: A Framework for Assessment*, P3.

[21] XIE Gaodi, XIAO Yu and LU Chunxia, Study on Ecosystem Services: Progress, Limitation and Basic Paradigm, Acta Phytoecologica Sinica, 2006, 30(2):191～199.

Overview of Supa Watershed

Supa is the first grade tributary flowing of Nu River with a main stream of 71.2km. Located in Longling County, Yunnan Province, the southwest of China, its drainage area is about 667 sq. km., accounting for 23.8% of the whole county. Supa River has an abundant quantity and numerous tributaries. Its average annual water yield is about 893 million m^3; 1700 meters of overall drop, 310,000 kw hydropower deposit, all of which make it the best resource for Longling county to develop hydropower. Now, development of hydroenergy resources in Supa watershed is in accordance with the program of “One Reservoir Five Hydropower Stations”. There has already built up 5 hydropower stations from 1993 till now with a total installation capacity of 253,000 kw. Though the environment of Supa watershed has not seriously deteriorated yet, its ecological environment is very fragile. About 61% of the area is the moderate fragile district, 31% slightly fragile district, 8% intensive fragile district. (See Table 1)

Table 1 Supa Valley Fragility Comprehensive Evaluation

Fragile Type	Quantity	Coverage（k ㎡）	Percentage（%）
Intensive Fragile District	11 small watershed (or the main stream slope)	54	8
Moderate Fragile District	78 small watershed (or the main stream slope)	407	61%
Slight Fragile District	91 small watershed (or the main stream slope)	206	31%

Source: XIE Pengchao and FU Baohong, “Evaluation and Study of Environmental Fragility in the Supa River Watershed” in LU Xing and HE Jun: *Payment for Environment Services: China’s Experiences of Rewarding Upland Poor*, Kunming: Yunnan University Press, 2009: 160.

Although soil erosion intensity of intra-Supa watershed is not very high (see Table 2), because of the fragile ecology in some areas, there exists potential ecological disruption. Slight erosion area accounts for about half of drainage area. Although proportion of intensive and extremely intensive corroded areas is relatively low, they are more centralized, which results in serious partial soil erosion.

Table 2 Hierarchical Form of Soil Erosion in Supa Watershed

Erosion Grade	Erosion Area（㎡）	Percentage（%）
No Erosion	246,305,342	36.52
Slight Erosion	322,790,398	47.86
Moderate Erosion	95,531,760	14.17
Intensive Erosion	78,97,500	1.17
Extremely Intensive Erosion	18,94,500	0.28
Gross Area	674,419,500	100.00

Source: ZHANG Jun, “Analysis of Land Utilization and Soil Erosion in the Supa River Watershed” in LU Xing and HE Jun: *Payment for Environment Services: China’s Experiences of Rewarding Upland Poor*, Kunming: Yunnan University Press, 2009: 167.

There are 4 counties, 26 village committees, two state-owned forest farms and a provincial nature reserve in Supa drainage area, where lives over 64,000 people, accounting for 23.32% of the whole county population. Most of them mainly engage in agriculture and forestry production, earning an annual income of about 1252 yuan per capita. Therefore, people live a comparatively poor life here. Land of Supa river valley is mostly used for forest and agriculture. Detailed conditions are shown in Table 3.

Table 3 Current Situation of Land Utilization in Supa Watershed

Land Utilization Pattern	Coverage (㎡)	Percentage (%)
Agricultural land	154,112,650	22.85
Forest Land	252,942,300	37.50
Open Forest Land	99,359,458	14.74
Shrub Land	162,909,000	24.15
Other Land Use	5,096,092	0.76
Total	674,419,500	100.00

Source: ZHANG Jun, "Analysis of Land Utilization and Soil Erosion in the Supa River Watershed," in LU Xing and HE Jun: *Payment for Environment Services: China's Experiences of Rewarding Upland Poor*, Kunming: Yunnan University Press, 2009: 165.

It can be said that Supa river valley is the integration of agriculture development, nature conservation and hydropower exploration, whose ecosystem service function maintains the local agricultural population and biological diversity as well as provides resources and guarantee for hydropower development. This study adopts sample investigation, chooses 120 peasant households (30 per village) in four administrative villages in upstream Supa River as respondents as well as carries on multiple investigations such as questionnaire and interview on the spot. The details of these 4 sample villages are shown in Table 4 and Table 5.

Table 4 Information Slip of Sample Villages

County	Population Person)	Inhabitant (Household)	Gross Area (mu)	Dry Land (mu)	Paddy Land (mu)	Tea Farm (mu)	Forest Land (mu)
Longxin	3228	745	41,922	2,200	1,578	570	27,938
Mengmao	5241	1,170	64,025	3,788	2,467	1,562	46,110
Xueshan	2739	626	33,114	2,080	847	1,315	15,981
Raolang	4281	998	55,768	1,912	2,839	1,434	25,848

Table 5 Economic Income in the Sample Village

County	Gross Income (CHY)	Average Income (CHY)	Main Income Source
Longxin	5209600	1017	Tea plantation, Farming production, Breeding industry, Out-migrating for Work, Transportation, Land lease etc.
Mengxu	14269100	1145	
Xueshan	3539000	932	
Raolang	6393000	956	

All of the 120 investigated peasant households are of Han nationality. Their family members vary from 3 to 7. The household with 3-4 people takes the dominance (74.2%) while the one with more than 5 people takes 25.8%. The total number of person of investigated people is 503, including 274 man and 229 women.

Among all investigated peasants, 405 are more than 16 years old and their occupations can be seen in Table 6. More than half (53.8%) adult relies mainly on farming and the next is temporary laborer, which accounts for 21.7%. Followed are student (5.9%), businessman （5.7%）, haulageman （4.0%） and teacher (3.2%) etc.

Table 6 Occupations of People above 16 from Investigated Peasant Households

Occupation	Number	Percentage ％
Peasant	218	53.8
Temporary Laborer	88	21.7
Student	24	5.9
Businessman	23	5.7
Haulageman	16	4.0
Teacher	13	3.2
Repairman	8	2.0
Civil Servant	7	1.7
Doctor	4	1.0
Worker	3	0.7
Police	1	0.2
Total	405	100.0

In the 218 people mainly engaged in agriculture, nearly 2/3 are women (61.5%) and over the 40 (61.9%). See Fig. 1 and Fig. 2.

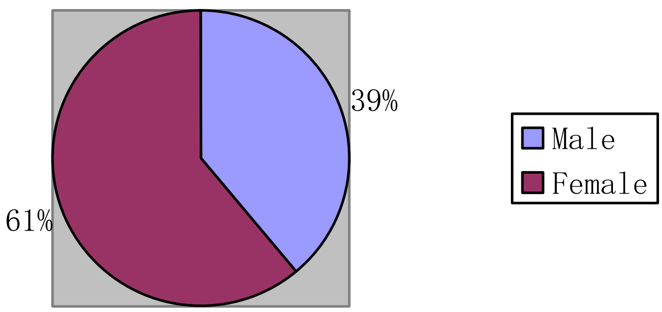

Figure 1 Peasant Gender Distribution

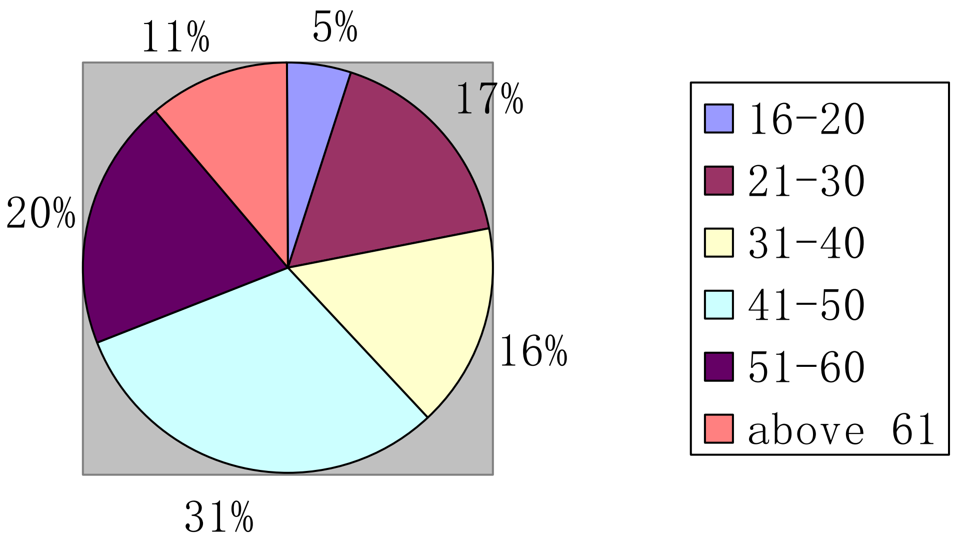

Figure 2 Peasant Age Distribution

2. Methodology: Value of Ecosystem Inherent Service Function

According to *Ecosystems and Human Well-being: A Framework for Assessment* from MA, ecosystem service function includes provisioning services, regulating services and cultural services, and these three kinds of services depend on supporting services, the most basic one. (See Table 7)

Table 7 Ecosystem Services

<table>
<tr><td rowspan="3">Supporting Services
Services necessary for the production of all other ecosystem services

■ Soil formation
■ Nutrient cycling
■ Primary productin</td><td>Provisioning Services
Products obtained from ecosystem

■ Food
■ Fresh water
■ Fuel wood
■ Fiber
■ Biochemicals
■ Genetic resources</td></tr>
<tr><td>Regulating Services
Benefits obtained from regulation of ecosystem processes
Climate regulation

■ Disease regulation
■ Water regulation
■ Water purification</td></tr>
<tr><td>Cultural Services</td></tr>
</table>

	Nonmaterial benefits obtained from ecosystems *Spiritual and religious* ■ Recreation and ecotourism ■ Aesthetic ■ Inspriational ■ Educational ■ Sense of place ■ Cultural heritage

Source：MA, *Ecosystems and Human Well-being: A Framework for Assessment,* P5.

Based on MA classification to the ecosystem service function, the investigation to 120 households in 4 administrative villages summarizes ecological service function of Supa River as follows.

2.1 Provisioning Services

The colony benefiting from the ecosystem supply service is mainly peasant households living in the basin. They get food, water, firewood etc. from the basin ecosystem to make their life guaranteed. Supply service function of Supa River ecosystem is mainly reflected on three land utilization –dry land, paddy land and forest land. Among the 120 investigated peasant households, most owned dry land (112), paddy land (114) and forest land (117). The average area of dry land, paddy land and forest land is 0.213 mu, 0.168 mu and 0.485 mu respectively. (See Table 8)

Table 8 Land Resource Possession in Investigated Peasant Households

Land Pattern	**House holds**	**Min Area**（mu）	**Max Area**（mu）	**Gloss Area**（mu）	**Average Area**（mu）
Forest Land	117	0.1	90	851.6	7.28
Paddy Land	114	0.1	9	287.4	2.52
Dry Land	112	0.2	9	357.9	3.20

2.1.1 Dry Land

Maize, tea, potato and walnut seed are mostly planted on dry land. And their cultivated area, output, input and output value are shown in Table 9. The maize is mainly for in-house use (feed livestock) and seldom sold. Most tea is sold to the local tea processing factory after plucking every April. And potatoes are sold to retailers. For walnuts, the majority of which are just planted, all the seed, fertilizer and membrane are offered by the government, so it costs farmers very little, about 250 yuan / mu on average. These walnuts take five years to bear fruit, 10 years to mid yield, and 15 years later to full fruiting in general.

Table 9 Dry Land Crops of Investigated Peasant Households

Crops	Household Number	Planting Area（mu）		Output（kg）		Cost（CHY）		Products Value（CHY）	
		Gross Planting Area	Average Planting Area	Gross Output	Average Output	Gross Cost	Average Cost per Acreage	Gross Value	Average Value per Acreage
Maize	98	193.8	1.98	31445	162.3	32830	169.4	53710	277.1
Tea	89	153.7	1.75	21800	141.8	6200	40.3	27065	176.1
Potato	46	36	0.78	18090	502.5	7945	220.7	19675	546.5
W	57	133.8	2.35	NA	NA	29000	216.7	45	3379.7

alnut								2200	

The NA walnuts are basically seedlings just planted, not bearing fruits yet

2.1.2 Paddy Land

Rice and wheat rotation is adopted on most paddy fields. Some peasant households (23) plant potatoes too. Table 10 reflects cultivated area, output, cost and product value of above three main crops. Most of rice and wheat are for in house use (as food or forage), seldom used for selling. Potatoes are mostly sold, either to retailers or to customers in market.

Table 10 Planting and Operation of Paddy Field Crops in Investigated Peasant Households

Crops	Households	Planting Area（mu）		Output（kg）		Cost（CHY）		Products Value（CHY）	
		Gross Planting Area	Average Planting Area	Gross Output	Average Output	Gross Cost	Average Cost per Acreage	Gross Value	Average Value per Acreage
Rice	106	260	2.45	42980	165.3	38040	146.3	77505	298.1
Wheat	102	247	2.42	34280	138.8	28470	115.3	55000	222.7
Potato	23	27	1.17	17400	644.4	7960	294.8	18465	683.9

*Most peasants adopt rice, wheat and potato rotation.

2.1.3 Forest Land

Among investigated 120 peasant households, 117 own forest land with a whole area of 56.773 mu. The trees mainly planted on forest land are weed tree, taiwania cypress and pine trees, accounting for 53.4%, 33.7% and 10.9% respectively. Other trees like mixed forest, wild forest, bamboo, etc. account for 2.1% of forest land. And most of peasant households plant two or more kinds of trees, some of which are used for selling, such as taiwania cypress and pine trees are mainly sold to timber factory while weed trees are mainly sold to brickyard. Planting and operation of forest land is shown in Table 11.

Table 11 Sale Situations of Trees on Forest Land of Investigated Peasant Households

Trees	Planted by households	Gross Cost	Gross Product Value（CHY）	Sale Proportion	Sale Time	Marketing Targets
Weed Trees*	86	4,580	417,700	22 households sell weed tree with a proportion varying from 20 to 60% and the majority sell 50%.	September	Brickyard and Timber Retailers
Taiwania Cypress	103	23,180	666,300	30 households sell taiwania cypress with a proportion varying from 10 to 100% and the majority sells 50%.	September	Timber Factories and Timber Retailers（10 years to be lumber）
Pine Trees	36	4,200	118,400	12 households sell weed tree with a proportion varying from 20 to 60%.	September	Timber Factories and Timber Retailers（10 years to be lumber）

* The weed trees were passed down by prior generation, so they can be sold directly without any cost.

The lands under trees are also planted amomum and dendrobium. In 120 investigated peasant households, 45 plant amomums with a total cultivated area of 148 mu. And 4 plant dendrobium for 3.5 mu. The costs of amomum and dendrobium are high, which is 454 Yuan and 64,286 yuan per mu respectively on average. But after the disposable input, they can grow for more than 10 years continuously to have a value up to 580 yuan and 41,714 yuan respectively on average for each mu. All the produced is basically used for selling.

In addition, a large area of forest in Supa watershed is included in Xiaoheishan Natural Reserve, a provincial nature reserve, which is build to protect forests and wild animals. The natural reserve protects wildlife resourses such as primitive Zhongshan wet evergreen broadleaved forest, rare spinulosa trees, wild rice, green peafowl etc. Now, there are 137 species or subspecies protection animals, 45 of which are national protection animals. What's more, 10 of them are the first class protected. They are green peafowl, slow loris, assamesemacaqure, presbytis francoisi, hylobates hoolock, red panada, pangolin, monitor lizard, python. Moreover, there are also 115 families, 278 generas, 475 spices known higher plants senior to fern in the reserve, among which 40 are national rare endangered plants and Yunnan key protected plants, such as spinulosa, wild rice, alcimandra catchcartii, Taxus chinensis, tetracentron sinensis, acrocarpus fraxinifolius, pterospermum kingtungense, tapiscia sinensis, manglietia insignis etc. Except that, many rare medicinal herbs grow in the natural reserve. It is also major water sources conservation region in Longling County, playing an important source in guaranteeing and promoting the sustainable development of local society and economy. [22]

According to the above-mentioned investigation, economic value that Supa watershed ecosystem service function offers to local peasant household can be summarized in Table 12.

Table 12 Ecosystem Values to a Household

Land Type	Area(mu)	Unit Output (CHY)	Total Output (CHY)
Paddy	2.52	650	1638
Rain-fed	3.20	277	886
Tea	1.75	176	308
Forest	7.28		560
NTFP	1.20	580	696
Water			
Total/HH CHY4088 (USD601)			

2.2 Regulating services

The regulating services function of Supa watershed ecosystem is mainly reflected on water and soil conservation. The groups benefited from this function are residents and hydro power company in the basin. Though ecological regime of Supa watershed is better now, water loss and soil erosion is hardly optimistic. Moreover, the soil erosion situation in some areas is very serious.

Since 1998, a total of 3424 mu farmland, 13 bridges, 1440.5 km road, 148.7 km channel and a retaining dam are damaged in the natural disasters in 4 counties of Supa basin, which causes an

[22] Colorful Yunnan, Our GreenHomestead：

http://www.ynepb.gov.cn/color/DisplayPages/ContentDisplay_213.aspx?contentid=8503 (accessed October 14, 2009) economic loss of about a million Yuan. Beside the serious economic losses, local masses' existence foundation is also wavered. [23]

Water loss and soil erosion plays a negative role on residents' living and production in the basin as well as development and utilization of water resources, causing heavy losses to power stations. According to written history, silt content for maximum section was 4.75 kilograms / cubic meter on average in 1991. The number was increased to 7.68 kilograms / cubic meter in 2001while silt content of minimum section was increased to 0.03 kilograms / cubic meter from 0.014 kilograms / cubic meter. [24] The increase of the silt content not merely causes silt deposit in a large amount in the reservoir, but is also harmful to generating equipments of hydropower station. For example, calculated with the present speed of soil erosion, service life of Qiezishan Reservoir--the highest hydro power station on Supa River--will be shorten to 30 years from 50 years. If taking the costs to maintain facilities destroyed by silt and flood as well as change apparatus etc. into consideration, 5 million yuan will be spent on hydropower station maintenance and loss each year.

2.3 Cultural services

Cultural service function of Supa watershed ecosystem is mainly reflected on development of local tourist industry. Because of the luxuriant vegetation and beautiful scenery in Supa basin, many places have become the travel destinations for recreation and amusement. The development of tourist industry has brought along the economic development in the neighborhood and increased peasants' income. For example, Qiezishan Reservoir has already become a tourist attraction to spend weekend or vacation. 5,000-10,000 tourists come here every year, bringing very great economic benefits to local community.

According to the above investigation, economic value brought by Supa watershed ecosystem provisioning service, regulate service and culture serve can be summarized as the following aspects.

The total value of Supa watershed ecosystem service function is USD10,040,647 every year, among which local peasant households obtain 89.8%, hydro power company 7.3% and the public 2.9%. And the cost reverting and keeping the ecosystem service function is USD2,449,497 every year, among which the local community pays for 20.24%, Hydropower Company 13.69% and the government 66.07%.

3.0 Results & Discussion: Management of Ecosystem Service Function

3.1 Irrigation system

Water is in a large demand in rice planting. During the period from sowing to the half a month before harvest (about 4-5 months in all), water is necessary in paddy land ("one inch water", aqueous layer should be an inch). It needs 50-60 tons of water to irrigate for each mu paddy field each time (including precipitation). While planting spring crops such as the barley, potato, rape etc. just requires two irrigations equally, about 60-70 tons of water for each mu each time (including precipitation).

The water can't be guaranteed for irrigation during the drought and there is no concrete

[23] LU Xing and LI Hetong, "Rewarding the Upland Poor for Environmental Services in the People's Republic of China," in LU Xing and HE Jun: *Payment for Environment Services: China's Experiences of Rewarding Upland Poor*, Kunming: Yunnan University Press, 2009: 132.

[24] LU Xing and LI Hetong, "Rewarding the Upland Poor for Environmental Services in the People's Republic of China," in LU Xing and HE Jun: *Payment for Environment Services: China's Experiences of Rewarding Upland Poor*, Kunming: Yunnan University Press, 2009: 132.

management and distribution method yet. Although channels are built on paddy land for diversion irrigation, basically there is no special-assigned person to operate channels at present. The irrigation should follow the order according to the distance between irrigation canals and paddy field owned by different peasant households. In other words, paddy field on the upper stream irrigation canals can have the priority to be irrigated. The field which is short of water is unable to plant in the aridity at present, the owners of which can only "depend on Heaven for food" and be cultivated on rainy days (commonly called as "field of thunder"). But in the years which have good weather, rainwater is very sufficient in the planting season with an average rainfall of about 2200 mm for many years. What's more, sprout cultivation technology on nonirrigated farmland is basically adopted right now to reduce water consumption.

3.2 Forest System

3.2.1. Felling of Forest

Firewood and timber are usually cut down in every autumn and winter because they are dry seasons and trees grow slowly, which is suitable for being cut down. The cutting down of firewood generally follows the principles of "keep the sparse branches and cut the dense" and "keep the good and cut the bad", cutting down the trees of poor growth or pruning. Meanwhile, the peasants should follow strictly corresponding felling targets given by county forestry bureau and relevant local rules and regulations. Otherwise they will be punished according to *Forest Law* and associated regulations. Felling targets are worked out according to *Forest Law* and relevant regulations as well as local forest growth amount (the felling should be less than the growing). Taking Raoliang County as an example, the felling target in 2008 is 700 m^3, including 340 m^3 timber and 360 m^3 firewood. Because of the local climate and other conditions, the trees do not grow fast and it takes nearly 10 years to reach the full size. Therefore, most of households just used timbers to build their house instead of selling now.

To the ones who steal and over chop for a little amount, is adopted the policy of relying mainly on educating and warning while making punishment subsidiary, which is always carried out by forest protection group or village committee(internal treatment). To the ones with serious cases or large stealing quantity, they will be punished by law enforcement agencies like forest public security according to *Forest Law* and relevant regulations. Felling trees and rearing livestock are forbidden in shelter belts protecting the headwaters of rivers. And the violating peasants will be punished in accordance with *Forest Law* and corresponding regulations.

3.2.2. Forest Protection Group

Local community has a high enthusiasm to ecological construction and maintenance. More than ten years ago, forest is assigned to each peasant household and a production team has been divided into several peasant groups. However, the ownership of the forest zone has been overlapped among different groups, so there are many wrong chop and over chop. Because the overlapping ownership on forest, it is inconvenient to manage and protect the forest taking peasant group as a unit. Then these peasant groups (basically within a production team) establish forest protection group together and peasants raise fund by themselves to employ forest ranger to manage the forest. But some peasant groups do not have such problems and they do not participate in forest protection group. Therefore, their control over forest zone is basically taking peasant household as a unit. Taking Longxin County as an example, there are 60% village communities implement unified forest management in this township, which costs 150,000 yuan every year.

At present, though recently finished forestry reform carries on a clear division on forest ownership, forest protection groups still exist. Because of the fast increase of undergrowth economy, sufficient utilization of forest resources and peasants' good forest protection consciousness, the peasants are willing to provide funds to employ rangers who are mainly responsible for firing prevention and guarding against theft. But there are also some peasants from the villager group with no regard on forest protection and a poor growth of undergrowth economy thinking that forest protection is economically inefficient, so they neither want to pay for forest protection, nor participate in forest protection group. In addition, in the villager groups whose group leader has a strong sense of responsibility, villagers are more likely to have a relatively better consciousness to protect forest and are apt to protect the forest jointly. However, some villager group has a weak and lax organization and poor leadership, it cannot handle its relation with villagers well. Meanwhile, villagers do not have a strong consciousness of protecting forests, so they are not willing to participate in forest protection group.

3.2.3 Xiaoheishan Provincial Nature Reserve

There are 21 staff in this nature reserve, who are attached to management department of forestry bureau and paid by government. More than 500,000 yuan is invested on the nature reserve by government and the reserve has pumped 7,500,000 yuan so far from its establishment in 1995. The reserve is managed on the basis of relevant regulations, mainly including *Forestry Law, Regulations of the People's Republic of China on Nature Reserves, Regulations of Yunnan Province on Nature Reserves, Integrated Management Program of Xiaoheishan Provincial Nature Reserve*, etc.

The relationship between natural reserve and local peasants is the combination of cooperation and contradiction. The contradiction mainly refers to villagers want to graze and cut down the firewood in the natural reserve, which are forbidden. But most villagers can observe the regulation of natural reserve. Cooperation mainly reflects on some activities, especially on Sino-Netherland Yunnan Province Forests Cooperative and Community Development Project, which engages in publicity, energy saving, guiding the industrial crops seedling, offering seedling, etc. Meanwhile, the management of the natural reserve and relevant activities have also brought along peasant household's protection and management of collective forest.

3.2.4. Public Welfare Forest

The majority of public welfare forest in Supa basin distributes in villages such as Heishan County, Xueshan County,etc., i.e. the village in the range of Xiaoheishan Nature Reserve. Most of public welfare forests are divided to be managed. Government puts into 4.5 yuan on each mu every year (including forest ranger's salary). These forest rangers are provisional and local common people, whose salary is calculated according to difficulty in management and area of the forest zone they manage.

3.2.5. Ecological Construction Projects by Local Government

The local forestry department draws support from national afforestation projects, successively launched a series of ecological construction projects in the basin. From 2002 to 2005, the governments at all levels has invested 11,007,854 yuan together, among which 9,170,954 yuan for returning farmland to forest, 588,820 yuan for rattan, bamboo and precious timber forest base, 103,550 yuan for relocated vegetation resuming, 341,050 yuan for afforestation in the waste mountains and lands, 282,230 yuan for management and protection charges for national key public welfare forest, 521,250 yuan for subsidies to fenced off for afforestation and 300,000 yuan for necessary expenses.

3.3 Domestic water

The running water can basically meet villager's demands at present, used mainly in potable water facilities for people and livestock, clothes washing, toilet flush (large water consumption), pigsty cleaning (relatively large water consumption),etc. Each household uses about 8 to 10 tons of water per month and about 96 tons to 120 tons one year.

Government pays for most of tap water pipe laying expense and peasant households pay the rest. Water meter is equipped in each household at present. Meanwhile, drinking water management association is established in each village, employing personnel to manage and maintain water pipe. Their salary (maintenance cost and charge for loss of working time) is paid together by villagers, which is 0.08 yuan for each ton of water. Every household pays about 0.6 yuan -1 yuan for water rent per month on average, which is 7 -12 yuan every year.

Because there is no industrial pollution around the village, the quality of running water is basically stable. But because of the lack of cleaning equipment in the cistern, water will be a bit muddy sometimes in rainy season (mostly at the time of torrential rain and heavy rain). Besides, amount of running water varies a lot in dry season and rainy season. Although water amount in dry season is less than that in rainy season, it can basically meet demand of peasant households.

Table 13 Water Rate of Investigated Four Villages

County	Population	Household	Monthly Water Consumption（Ton）	Monthly Water Rate （CHY）	Annually Water Consumption （Ton）	Annually Water Rate （CHY）
Longxin	3,228	746	5968~7460	478~746	71,616~387,360	5,222~8,952
Mengmao	5,241	1170	9360~11700	702~1170	11,2320~140,400	8,190~14,040
Xueshan	2,739	626	5008~6260	376~626	60,096~75,120	4,382~7,512
Raolang	4,281	998	7984~9980	599~998	95,808~119,760	6,986~11,976

3.4 Hydropower company

As modern enterprises, hydropower companies care their economic benefits most. Supa Hydropower Development Co., Ltd. is a shareholding company and it pays great attention to its corporate image in the local community. During construction of power station, it builds highway and school for the local community, thus keeping the benign relation with the locals. The company is in accordance with the relevant laws and regulations of environmental protection, tries hard to reduce the negative influence on ecology of building power station and resumes the unavoidable ecological disruption too. Hydropower company regards the government is bearing the duties of ecological construction and protection, so the company does not have to compensate for and repair the ecological destruction caused by hydropower station operation. However, soil erosion has shortened the service life of the reservoir and generating equipment, which has caused the enormous economic losses to hydropower company. So the company has written to the Longling county government, expressing clearly the willingness to offer certain financial support for improvement and maintenance of the ecological service function in the basin as well as the hope to get the clear repayment for its input to improve the ecology quality, which is the guarantee of prominent reduction on soil erosion and reservoir deposition. [25]

4. Conclusions

4.1 As an integrative basin with agriculture, nature conservation and hydropower developing, ecosystem service function of Supa watershed is mainly reflected in sustaining agricultural population's livelihood, maintaining bio-diversity and ensuring the hydroelectric generation.

4.2 The local governments at all levels have offered a large amount of fund and technical support to ecological construction and maintenance in Supa watershed. Local rural community has also paid a

[25] LU Xing and LI Hetong, "Rewarding the Upland Poor for Environmental Services in the People's Republic of China," in LU Xing and HE Jun: *Payment for Environment Services: China's Experiences of Rewarding Upland Poor*, Kunming: Yunnan University Press, 2009: 135.

large amount of labor and fund to manage and protect forests. Supa Hydropower Development Company attaches great importance to the ecological construction in the basin as well, providing funds building and safeguarding the ecosystem service function in the basin to guarantee normal operation of five hydropower stations.

4.3 The ecosystem protection system (such as forest protection group) set up by local rural community plays a most basic but direct role and influence, which must be paid attention to. Hydropower Company and local government should provide these community protecting systems with technology and fund to strengthen their management and protection function.

5. Future Directions

Government is the main force on the basin ecological construction and protection. Because of the backwardness of economic development in the basin, peasants live in penury, willing but unable to construct and protect the ecosystem service function. Besides, hydropower company pay most attention to its own interests, willing to get clear repayment through ecosystem protection. But ecosystem protection is a long-term course. It is difficult to guarantee that hydropower company can get the benefit corresponding to the interest it requires. So, the watershed ecosystem protection demands government providing not merely fund and technology, but creating an environment participated actively by local peasants and hydropower company.

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Chapter 7

An indicator – based integrated assessment of ecosystem change and human-wellbeing: Selected case studies from Indonesia, China and Japan

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Abstract

The utility of Participatory Rapid/ Rural Appraisal (PRA) as a sociological methodology to identify revealed preferences of a group/ community has been well established. Similarly, integrating PRA methods as a means of ground-truthing satellite data on changes to natural systems has also been explored successfully by several researchers. In the current study, in order to value sub-montane ecosystems from study areas in four regions in Asia-Thailand, Indonesia and China, Japan- a multi-stakeholder PRA approach is utlised to capture revealed preferences and values that the ecosystem services hold to the different stakeholders who gain utility from them. We observed that the process serves 3 main purposes-(1) it provides a better representation of the preferences of different stakeholders of ecosystem services (2) it fosters validation of data between the different stakeholders and (3) enables a communication and planning process among the stakeholders to sustainably utilize and manage their ecosystems. The use of spatial maps validates the relevance and utility of diachronic observations of communities and other stakeholders directly dependent on ecosystems. At the same time, they can be used to strengthen local planning processes for the development of services in the ecosystem, of relevance to humans and nature. Such research thereby also acts as a catalyst to a social process of coordinated action to address local issues of global relevance.

I. Introduction

Over the last three decades, the intricate relationship between ecosystem health and human welfare has been fairly well-acknowledged, even if not completely defined or specified (Millennium Ecosystem Assessment, 2005; Costanza and Folke, 1997). The third Global Biodiversity Outlook (GBO) reiterates that we are losing productive and valuable ecosystems rapidly, accelerated primarily due to anthropogenic factors related to land use (Secretariat of the Convention on Biological Diversity, 2010). Southeast Asia, like other tropical regions, has also witnessed large scale changes to ecosystems, and is considered one of the three major bio-cultural diversity hotspots in the world (Maffi, 2007).

A research project that focused on studying the implications of various ecosystem management / use measures to human well-being was undertaken in selected southeast ecosystems in China (in the Supa Watershed area, Yunnan Province), Japan (Kushiro watershed area, Hokkaido, a Ramsar wetland site), Indonesia (Bawan village, Kahayan watershed area, Palangkaraya, Central Kalimantan) and Thailand (Mae Hae Watershed area) in 2009. This paper highlights the findings of the study from the study areas of Indonesia, China and Japan. The study sought to trace changes to productive resources of ecosystems over a period of 50 years (1960's to 2009); and 2. To trace the dependence of wellbeing of local population on the ecosystems for the same time period. To illustrate the changes, we develop an indicator-based assessment framework that integrates data from biophysical and socio-economic parameters. Section 2 details the methodology followed in the collection of data and development of indicators, and Section 3 provides a discussion of the results obtained and inferences.

2. Objectives and Methodology

The study attempted to trace changes to ecosystems and dependence of human well being on them over a period of fifty years (from the 1960s) considering the ease of 'harvesting the memories' of older members of the communities. Acknowledging that this is a minor time scale to capture absolute changes ecosystems given the chronology of ecological events (Limburg *et al, 2002)*, it was still a period of both intensive and extensive changes to land use practices around the world (MA, 2005)). While net changes are bound to occur over this time frame, we considered it worthwhile to investigate the process through which such changes occurred in the study sites. For this purpose, data was obtained from remote sensing data (LANDSAT images) and from social surveys in the selected regions. To enable analyzing the changes to ecosystems, changes to various services provided by the ecosystem were noted. This followed the classification of services as per the Millennium Ecosystem Assessment framework: Provisioning services (such as food, fuel, medicine, livelihoods), Supporting services (such as soil formation and retention), Regulating services (such as water quality, flood control, etc) and cultural services (including for recreational, spiritual or cognitive purposes)[26].

Data was obtained through two means: (1) for the remote sensing data, it was obtained from LANDSAT images. For data prior to 1989, we relied on the information gathered from the social survey , except in Kushiro watershed area in Japan, where GIS data was available(2)To obtain socio-economic data, participatory rapid appraisal (PRA) methods were followed in a multi-stakeholder forum[27] involving major actors from within the ecosystem. This forum included farmers, shamans, village leaders, elders, traders, women among others following different vocations. They were formed into representative groups to discuss changes related to their biophysical endowments in

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[26] **Provisioning services** are: The products obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water. **Regulating services** are: The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases. **Cultural services** are: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values. **Supporting services** are: Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat. (from the MA, 2005)

[27] For this study, the stakeholders from within the ecosystem were considered as comprising a community or a unit.

the region, theirsources of income(details regarding various ways income flows and approximate proportions in terms of people employed and scale of flow), and items of expenditure (including details on expenses on basic requirements such as food, fuel, clothing and others such as savings, education, etc and source from where the service/ good is obtained), details regarding their livelihoods, and role and effectiveness of institutions (such as school, hospitals, banks, government and non-governmental organizations, etc) in their context. Leading questions on changes to natural endowments, policies on land use and management, and production and consumption behavior of the respondent communities were discussed during the PRA, and follow up interviews. As the data pertained to their actual decisions, it reflected their preferences as revealed through their actions. The multi-stakeholder exercise helped to validate information provided by the different stakeholders with respect to their livelihoods, past disturbances to the ecosystem, attendant drivers and interventions and consequences. It also helped to identify resource persons or principal informants who could be contacted for further information.

While the utility of integrating spatial and social science research methods has been highlighted earlier (Vogt et al, 2006; McCall, 2003; Hassan et al, 2005), an attempt has been made here to draw inferences from both data sets by bringing them together in a value neutral scale through the use of appropriate indicators. It is therefore an effort endeavoring to link what is considered objective science with revealed perceptions and preferences of different stakeholders who are based in the immediate vicinity of the ecosystem.

2.1 Indicators and Scoring

As pointed out by Limburg *et al (ibid),* the applicability of economic welfare valuations in the context of ecosystem utilization is hampered by changes to preferences and perspectives from new information, thereby suggesting that such uncertainty may best be captured through appropriate indicators that provide clear directions for policy decisions and implementation. The MA approach also highlights the need to focus on trade-offs, through appropriate indicators to enable land use decisions (Hassan *et al* 2005). The present study concurs with this argument and is concerned with demonstrating that participatory processes of research can provide a stakeholder-centric basis for the development of ecological and economic indicators that provide clues to trade-offs made till date, and trajectory that needs to be followed for the future.

The collected data was analyzed for:

- Changes to ecosystem services
- Changes in dependence of well-being of the population on Ecosystem services
- Changes to Resilience of :
  - ecosystems
  - human well-being

2.1.1 Changes to Productive Resources (Biophysical)

In the context of this study, an ecosystem is taken to be the whole unit(s) of natural environment which forms the frame of biophysical reference to communities residing therein. The case studies are all located in terrestrial forest-based ecosystems, encompassing inherent water bodies, crop lands, plantations, or orchards, infrastructure and other land uses. Changes to such production-based land use systems, however have been accounted for under socio-economic indicators, as they relate to Provisioning services. Indicators chosen to reflect changes to biophysical resources within the forest ecosystems and can be broadly categorized under the Supporting and Regulating services of ecosystems. Hence, data on biophysical parameters related to changes to forest area, resource availability, soil quality and flood frequency were collected. These include:

1. Forests: The major biophysical indicators in forest ecosystems include extent of forests and availability of forest resources and other essential services that can be obtained from forests. Keeping in line with the MA framework, and ease of data collection within the project's timeframe, the following indicators were defined.	
A. **Change in area of forests** was the indicator chosen to capture gross changes to the ecosystem from land use maps. Land use maps were plotted between 1989 (the latest year for which good quality maps are available) and 2005/ 2009, and based on these maps, a Land Use Transition matrix was worked out (see e.g. Table1 for Supa Watershed area). This matrix shows the loss or gain of land to various land use activities (including forest land, infrastructure, water bodies, farming and plantations, etc) over a period of time. The scores were defined as follows	*1. >75% of forest area is still retained-high level of forest cover maintenance (2),* *2. 50-75% - fairly high level of forest area retained (1),* *3. 25-50% - intermediate as there is a possibility of movement on either side- (0),* *4. 10-25% - low level of forest area retained (-1),* 5. *<10% - significantly low level of forest area retained* (-2)
B. **Change in volume of resources obtained from the forests**: This refers both to floral, faunal and non timber forest products obtained from the forests. The data was obtained during multi-stakeholder PRA interviews.	*1. >75% of forests resources still available (2),* *2. 50-75% of forests resources still available (1),* *3. 25-50% - intermediate - (0),* *4. 10-25% - decline in availability (-1),* 5. *<10% - significant decline in availability* (-2)
2. **Flood frequency** : this indicator was considered useful to indicate the change in regulatory services of the ecosystem. Data for this was obtained from the PRA interviews**.** Participants were asked to note changes between the years on the number and frequency of flood events, that related to overflowing of waters from natural water bodies such as rivers or lakes. Recognizing that natural flood events might be a regular feature in ecosystems with water bodies, we aim here to capture if over the period, there have been changes to such events, and its implications	*1. If flood frequency has increased to >75% from earlier period, indicates very high loss of water regulation capacity (-2),* *2. If flood frequency has increased to 50-75% from earlier period (-1),* *3. If flood frequency has increased to 25-50% from earlier period (0),* *4. If flood frequency has increased to 10-25% from earlier period (1),* *5. If flood frequency has increased to <10% from earlier period (2)*

3. **Soil Quality Index:** A soil quality index that estimates change in soil properties due to land use was developed for Bawan village. Soil samples for different land use types, including Peat Swamp forest were collected and analyzed for pH, CEC, C:N ratio, phosphorus and Soil respiration. The initial vegetation (20 years ago) was Peat swamp forest so the site where the Peat swamp forest vegetation was still intact as at time of sampling was used as the control. Expressed as a percentage change (X) over undisturbed Peat soils, the limiting effects of extreme data values were removed by using the formula *Revised X = (X- Min value)/(Max-Min Value) for each characteristic for all land use* Following this, by providing a uniform weight of 20% to each characteristic, the sum of the Revised X values for characteristic across a land use was calculated to give the change in soil quality over undisturbed peat for each land use. Further, summing over the individual soil qualities, provides an indicator of overall Soil quality that ranges from 0 to 1. Values of zero implies the soil has virtually lost the quality of peat with respective to a given soil property, whereas values of 1 means that peat characteristics with respect to the property is still intact. The scores for the index were defined as follows	1. *If > 0.75 of original peat quality, maintenance of high quality(2)* 2. *If 0.50-0.75- fairly high quality still maintained(1)* 3. *If 0.25-0.50 - intermediate (0)* 4. *.10-.25 - low quality(-1)* 5. *<.10 - significantly low quality(-2)*

2.1.2 Indicators for Socio-economic parameters

Changes to dependence of human wellbeing on the ecosystems would indicate the relative extent to which population in a given natural ecosystem continues to use various services provided by the ecosystem for their various requirements. Any ecosystem assessment process should be able to capture economic, ecological and sustainability parameters translating to economic efficiency, ecological sustainability and distributive justice (Costanza and Folke, 1997). As mentioned earlier, the data represents the revealed preferences of the different stakeholders in the community(ies) obtained from multi-stakeholder PRA interviews, thereby representing actual decisions and drivers related to ecosystem use in the regions. The indicators chosen capture dependence of the immediate population on the ecosystem for meeting their various requirements of well being that include: basic needs (such as for food, fuel, clean water and health), for their livelihoods and their spiritual requirements. The role of culture in augmenting ecosystem health has been well acknowledged (Zent and Maffi, 2009), as in order to meet certain cultural priorities, several attendant actions of benefit to the ecosystem need be taken. For instance, maintaining sacred groves involve ensuring the resources within are well governed and utilized. The socio-economic indicators and scores were defined to chart sustainability concerns within an ecosystem context, as follows:

Indicator	*Scores*
1. **Food self-sufficiency:** this considered the extent of dependence of the population on the ecosystem to meet demand for staples such as Rice, vegetables, meat, fish. The participants of the PRA exercise noted volumes approximately consumed of these staples within the community (on a per household level), and changes to sources of these staples over the years.The scores were defined as follows:	1. *If > 75% of items were obtained from the ecosystem , very high dependence (2)* 2. *If 50-75%- high dependence (1)* 3. *If 25-50% - intermediate (0)* 4. *10-25% - low dependence (-1)* 5. *<10% - significantly low dependence (-2)*
2. **Fuel self-sufficiency:** this considers the extent of dependence of the population on the ecosystem to meet demand for fuel for household purposes. Again, the PRA participants noted their fuel requirements, and sources to meet them over the years. The scores were defined as follows:	1. *If > 75% of fuel requirements were obtained from the ecosystem , very high dependence (2)* 2. *If 50-75%- high dependence (1)* 3. *If 25-50% - intermediate (0)* 4. *10-25% - low dependence (-1)* 5. *<10% - significantly low dependence (-1)*
3. **Access to clean water:** considers 'ease of procurement'/ availability (sources and restrictions on accessing them) and quality of water. The scores are defined as follows:	1. *If easy access to available good quality water from the ecosystem- very high dependence (2)* 2. *If restricted access to good quality water- high dependence (1)* 3. *Easy access to water requiring minimum treatment- intermediate (0)* 4. *Easy access to polluted water – low dependence (-1)* 5. *Restricted access/ unavailability of water – significantly low dependence (-2)*
4.**Health security:** considers dependence on Ecosystem to meet health care requirements (in terms of medicinal resources used and who delivers health care). The scores were defined as follows:	1. *If all medicinal resources and healthcare from within ES – very high dependence(2)* 2. *If resources and healthcare primarily from within ES- high dependence (1)* 3. *If some resources and healthcare from within ES – margin (0)* 4. *If either resources or healthcare from within ES – low (-1)* 5. *If neither resources nor healthcare from within ES – significantly low (-2)*

5. **Livelihood dependence/ security**: considers number of economic activities, number of traditional activities (defined as activities that have been followed over generations) and number of profitable and value addition activities in order to capture if activities from within the ecosystem are driving the economy. There are 2 sub-indicators defined under this:	
A. Proportion of number of traditional activities based on ecosystem services to total number of livelihood activities (this indicates the extent to which traditional practices continue to be a part of the economic activities to the population)	1. *If proportion = 1 – very high dependence (2)* 2. *0.5 -0.7 – high (1)* 3. *0.25-0.5 – intermediate(0)* 4. *0.1- 0.25 – low (-1)* 5. *<0.1 – significantly low (-2)*
B. Proportion of profitable production and value addition activities based on ecosystem services to total number of livelihood activities (indicates the extent to which activities from within the ecosystem drive the monetary economy of the community. It includes both traditional and new activities)	1. *If proportion = 1 – very high dependence (2)* 2. *0.5 -0.7 – high (1)* 3. *0.25-0.5 – intermediate (0)* 4. *0.1- 0.25 – low (-1)* 5. *<0.1 – significantly low (-2)*
6. **Cultural dependence**	
A. **Sacred areas:** Maintenance of sacred areas would require abiding to certain governance norms, and utilisation of natural resources and components of the ecosystem for cultural or spiritual purposes. Hence, this was considered a useful indicator and factors such as the presence and degree of governance of sacred areas were included. Scores were defined as follows:	*1. Present and governed (frequently checked and upkeep maintained) well –very high dependence (2)* *2. Present but not actively governed (occasional checks for ceremonial purposes)- high dependence (1)* *3. Present but not governed/ managed (left undisturbed, neglected) – intermediate(0)* *4. Present and poorly managed (exploited) – low dependence (-1)* *5. Absent/ Degraded – significantly low dependence (-2)*

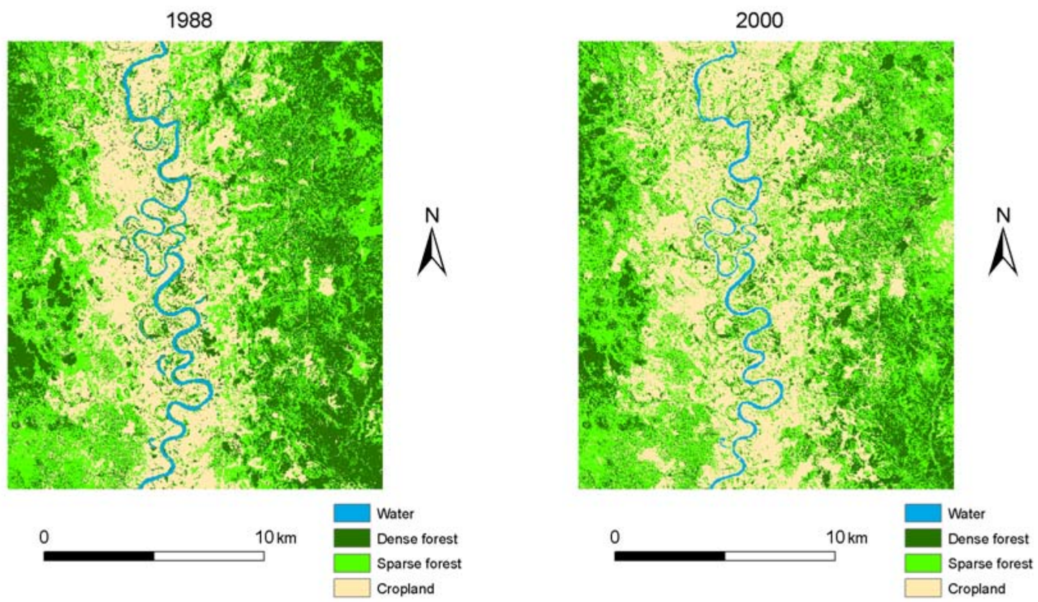
3. Results and Discussion

3.1.1Changes to Biophysical Characteristics

1. **Forest Area :** In Bawan, more than 75% of the forest area is still present (Table 1, Fig 1), although the decline of dense forest area has been to the extent of about 10 per cent. Interviews and responses from the PRA indicate that within this area, there have been cases of large scale logging, deforestation, and degradation in particular areas. Reasons for deforestation were in this case primarily led by private commissioning of forest areas by the

government for logging, and resettlement of people from other provinces without appropriate planning for their livelihood activities or appropriate sensitization to use of natural resources. Such policies and related land use decisions have affected other productivity indicators of the ecosystems, such as soil quality.

Fig 1: Land use maps for Bawan village 1988-2000



1988	2000					
	Water	Dense Forest	Sparse Forest	Cropland	Total 1988	Loss
Water	1.52	0.00	0.14	0.40	2.06	0.54
Dense Forest	0.00	21.85	7.58	2.58	32.02	10.17
Sparse Forest	0.00	0.00	22.00	12.67	34.67	12.67
Cropland	0.00	0.00	7.83	23.42	31.25	7.83
Total 2000	1.52	21.85	37.56	39.07	100.00	31.21
Gain	0.00	0.00	15.56	15.65	31.21	

Table 1: Land Cover Transition Matrix-Bawan 1988-2000 (%)

The case of the Supa Watershed makes an interesting study. While the current forest area still retains more than 75 % of the acreage from 50 years ago, the last few years have witnessed a net increase in the area of forests. The land transition matrix for the region for the period 1989-2001 indicates that there has been a net increase of 14.1% of forest land (dense and sparse forests) (Table 2, Fig 2). This has been primarily driven by the government’s policy to return land to forests put in place since the year 1999.

1989	2001						
	Dense forest	**Sparse forest**	**Water**	**Grassland**	**Farmland**	**Total 1989**	**Loss**
Dense forest	37.10	5.14	0.00	1.69	1.10	45.03	7.93
Sparse forest	2.20	6.84	0.00	2.48	0.40	11.92	5.08
Water	0.00	0.00	1.92	0.00	0.00	1.92	0.00

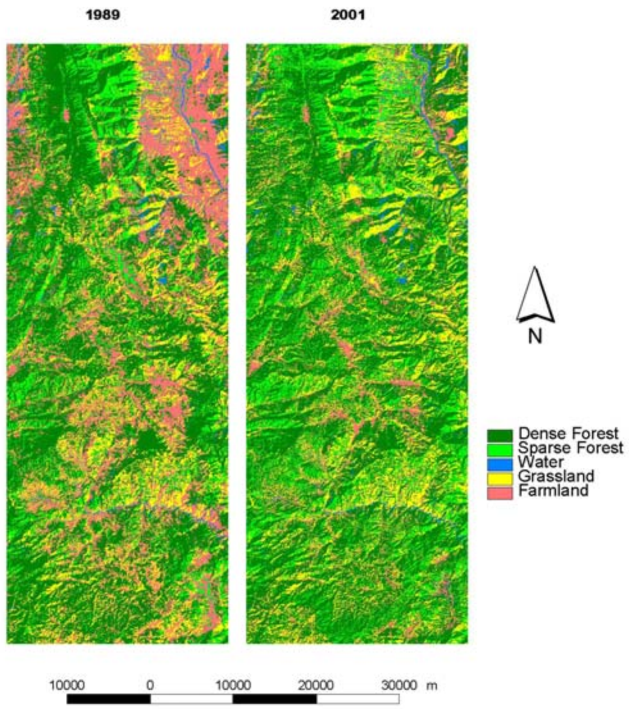


Fig 2– Land use maps for Supa 1989-2001

Table 2: Land cover transition matrix in Supa watershed 1989-2001 (%)

Grassland	1.76	2.97	0.00	10.45	0.90	16.09	5.64
Farmland	13.19	1.84	0.00	4.59	5.43	25.04	19.61
Total 2001	54.25	16.79	1.92	19.21	7.83	100.00	38.26
Gain	17.16	9.95	0.00	8.76	2.40	38.26	

In Kushiro, around 10 % of forest area was lost primarily for agriculture use, primarily for development of pastures and dairy farming that was promoted by the National Government since the 1980s, due to favorable weather conditions (Table 3, Fig 3). The number of farming households reduced by about 55 % between the two periods, resulting in agriculture becoming a large scale activity (from PRA interviews). It may also be noted that by the 1970s, infrastructure development had almost saturated in the region enabling it to be well connected to different growth centers.

Figure 3 Land use area in Kushiro 1976 and 2006 (unit: ha)

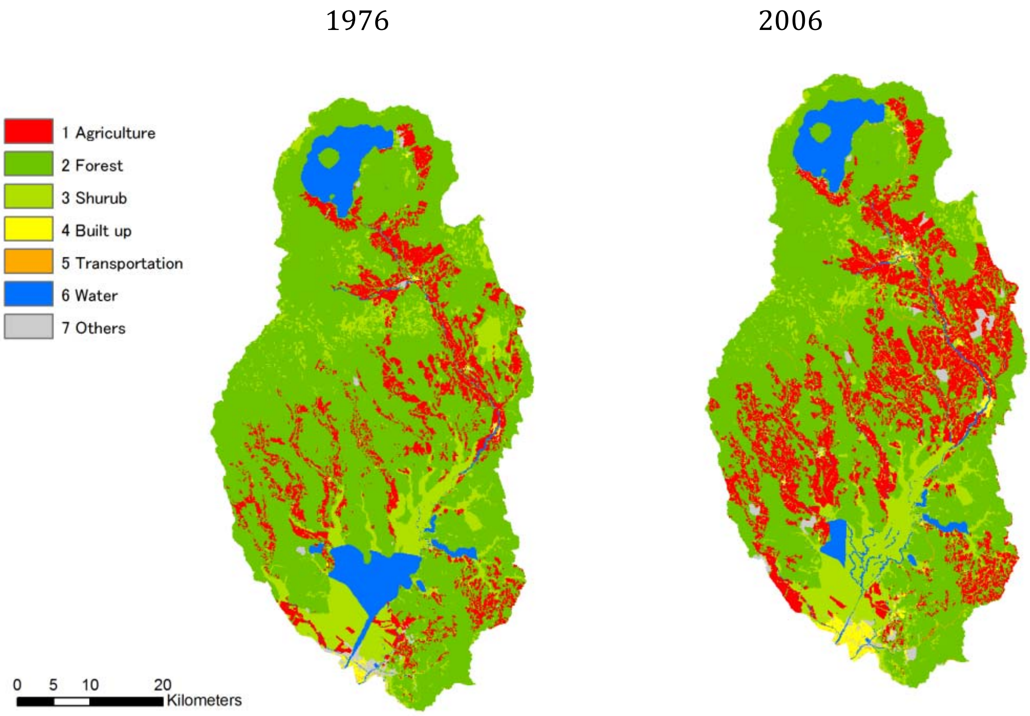


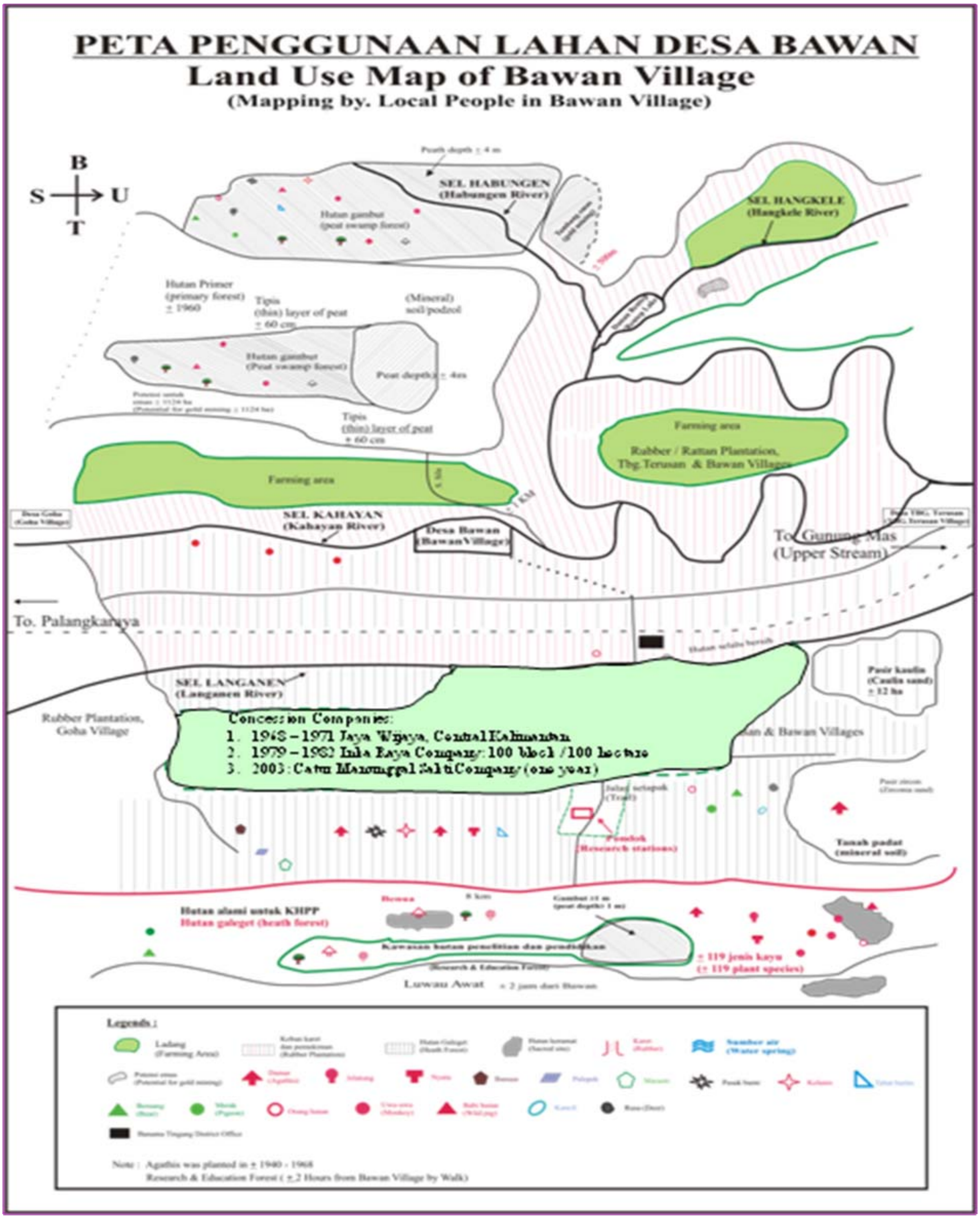
Table 3 Land cover transition matrix in Kushiro

Year 1976	Year 2006								
	Agriculture	Forest	Shrub	Built up	Road	Water	Others	Total in 1976	Loss
Agriculture	7.44	3.78	0.74	0.35	0.20	0.20	0.23	12.95	0.00
Forest	11.41	50.09	3.88	0.27	0.34	0.58	0.70	67.27	9.70
Shrub	2.24	2.98	5.39	0.29	0.06	0.28	0.37	11.61	0.00
Built up	0.04	0.04	0.01	0.21	0.01	0.02	0.03	0.37	0.00
Road	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.03	0.00
Water	0.24	0.52	2.01	0.10	0.02	3.96	0.12	6.97	1.88
Others	0.06	0.14	0.11	0.29	0.03	0.05	0.13	0.80	0.00
Total in 2000	21.44	57.56	12.15	1.52	0.67	5.09	1.57	100.00	11.58
Gain	8.48	0.00	0.54	1.15	0.64	0.00	0.78	11.58	

2. **Change in volume of forest resources:** In Bawan village, even now about 75% of forest resources are still available. However, their spread has reduced in areas especially near the polluted water body, and degraded forest areas, but is high in sacred and educational sites. The PRA map generated during the PRA shows the changes to biophysical resources and to availability of flora and fauna over the years (Fig 4), along with policy events that marked eventful changes during the period.

   In Supa watershed, resource availability has improved by 20 % from previous time period, primarily driven by expansion of forest area. In Kushiro watershed, while the population of migratory birds such as cranes has increased due to increased environmental activities promoted by a not-for profit organization in the region with the support of the government, native animals have become endangered ad vulnerable (from IUCN Red List Ver.3.1 (2001; PRA interviews) and the extent of use of forest products is marginal now (from PRA interviews).

Figure 4: PRA map on Land use in Bawan village



3. **Flood frequency** : In Bawan, the flood frequency has increased dramatically over a period of 50 years. The region was subjected to flooding about 1 to 2 times 50 years ago. Of late, this has increased to around 4 times a year. The regulatory effect of the natural landscape appears compromised and the reasons attributed include higher sedimentation of the Kahayan River, primarily from deforestation, intensive agricultural activities and illegal mining. Already, as the villagers indicated, this has led to the excessive overflow of the Kahayan River resulting in changes to the contours of the Bawan village thrice between 1948 and 2009. There were no incidents of flooding reported from Supa and Kushiro for the time period.

4. **Soil Quality index**: An important indicator to the extent of degradation of ecosystems, and implications to its productivity, is the quality of soils. The soil quality index as worked out for this study indicated that it had declined by about 54% in Bawan village area due to human impact (Table 5).

Table 5: Average values of soil characteristics for different land uses in Bawan 1989-2009

Previous vegetation (20 years ago)	Vegetation at time of sampling	pH	P	CEC	C	N	CN	res
Peat swamp forest	Cassava	4.07	37.23	139.72	55.04	1.11	49.49	2.09
Peat swamp forest	Ipomea and Spinach	4.56	158.83	139.70	54.21	1.04	52.31	1.83
Peat swamp forest	Rubber	4.11	16.70	141.07	53.26	1.17	45.57	1.83
Peat swamp forest	Post forest fire	3.47	18.93	138.26	54.96	1.03	53.48	1.69
Peat swamp forest	Pumpkin	4.31	182.67	133.53	52.87	0.97	54.51	1.85
Peat swamp forest	Peat swamp forest	3.37	17.30	182.64	57.20	1.14	50.26	2.09
Peat swamp forest	Corn	3.63	101.17	147.03	54.33	1.02	53.30	1.83
Peat swamp forest	Ramboutanake	3.54	96.37	123.88	53.27	1.16	45.85	1.76
Peat swamp forest	Peanuts	3.52	81.43	137.77	54.57	0.98	55.55	2.27
Peat swamp forest	Ocimum canum	3.47	160.43	119.55	53.95	1.11	48.64	2.24
Peat swamp forest	Rice field	3.69	21.50	103.01	53.40	1.10	48.64	1.69
Heath forest	Secondary Heath Forest	4.12	7.25	3.70	1.46	0.21	7.09	2.22
Peat swamp forest	Peat Swamp Low Disturbance	3.38	16.37	71.39	26.44	1.01	26.15	2.26

Table 6: Changes in soil properties for different uses relative to soils of natural peat swamp forest and soil quality index

Crop	Ph	P	CEC	CN	res	Soil quality
Cassava	0.59	0.17	0.95	0.13	0.31	0.43
Ipomea and Spinach	1.00	0.86	0.95	0.07	0.75	0.73
Rubber	0.62	0.05	0.96	0.21	0.75	0.52
Post forest fire	0.07	0.07	0.94	0.04	1.00	0.42
Pumpkin	0.79	1.00	0.91	0.02	0.72	0.69
Corn	0.21	0.54	1.00	0.05	0.75	0.51
Ramboutanake	0.14	0.51	0.84	0.20	0.88	0.51
Peanuts	0.12	0.42	0.94	0.00	0.00	0.29
Ocimum canum	0.07	0.87	0.81	0.14	0.06	0.39
Rice field	0.26	0.08	0.69	0.14	1.00	0.44
Secondary Heath Forest	0.62	0.00	0.00	1.00	0.09	0.34
Peat Swamp Low Disturbance	0.00	0.05	0.47	0.61	0.03	0.23
					Overall Soil Quality	**0.46**

Notes: Here soil quality under different land uses or cover is expressed as a proportion of the soil quality of natural peat swamp forest. Values of zero implies the soil has virtually lost the quality with respective to a given soil property, whereas values of 1 means that the characteristics with is still intact. Intermediate values indicate how human impact has modified soil properties relative to soil under natural peat swamp forest. The last column indicates the diminution in soil quality once conversion from natural peat forest to a given cover or use occurs. For instance we can say that there is 57% degradation in soil quality when natural peat swamp forest is converted to cassava. Ipomea degrades soil quality the least (by 37%), whereas disturbed peat degrades it the highest (by 77%). Taken together, human impact has led to 54% degradation in soil quality relative to soil under natural peat swamp forest.

The biophysical characteristic trends in Bawan village clearly indicate increasing degradation of the ecosystems. While land use changes and decisions related to land use have given rise to this situation, it is pertinent to note that some of the more adverse degradations were prompted by policies that were meant to increase development indicators in the region. However, they ended up fostering exploitative and unsustainable cultivation practices.

Table 6: Changes to Biophysical parameters in Bawan village

Indicator	Score (Change in status of parameter between the two periods)			Remarks
	Before	After	Change	
Forest area	2	2	0	About 10 % decrease in forest area (1989-2000)
Forest resources	2	2	0	More than 75% of resources still available, although severe degradation seen in some pockets (1960s-2009)
Flood frequency	-2			More than 100% increase in flood frequencies, attributed to climatic factors, and loss of regulatory capacities of forests (1960s-2009)
Soil quality	-1			Reduction in total soil quality by more than 50% of original peat characteristics. (1989-2009)

3.1.2 Changes to dependence of well-being on Ecosystem

Security of food, fuel, water, health, livelihoods and culture were considered central to ensure the well being of the population. The study attempted to chart to what extent the dependence of the population on the ecosystems to meet their well being needs has changed over the years. Changes also reflect the extent to which the ecosystems continue to provide various utilities to the people, and thereby focus attention to challenges in meeting those objectives.

1. **Food Security:** The villagers in Bawan traditionally were self sufficient for their major food staples- including rice, corn, vegetables. Even now, their production activities are aimed towards self-consumption (more than 80 % of food consumed is from the ecosystem), indicating a high dependence on the ecosystem to meet this basic need. They currently spend about 20 % of their income on food expenses. Food self sufficiency has been on the decline, due to a variety of factors such as:
    a. Unseasonal rains and episodes of frequent flooding
    b. Change of farmlands to plantations- Before the 1960's, rubber plantations in the area were small (<2 ha). However, recently the region has witnessed an expansion in rubber plantations along the Kahayan watershed that were originally lowland rice growing areas.

c. Loss of productivity of crops – interviews showed there has been a reduction in both corn area and productivity; whereas, in the case of rice, while the net rice area cropped has remained more or less constant, yield levels have gone down. Since 2004, the villagers have been supplementing their production with market purchases to meet their consumption demand.

The condition in the Supa Watershed area in Yunnan province (China) is similar to Bawan with more than 75 % of the food consumed coming from the ecosystem. However, in the Kushiro watershed area (Japan), less than 10% of the food (in the form of some vegetables) consumed by the population comes from the ecosystem, the rest being supplemented by imports that was facilitated by well developed transportation systems and infrastructure. The respondents remarked that they had heard that till the 1950s, the dependence of the people on their immediate ecosystem for their food requirements was very high.

2. **Fuel sufficiency:** dependence on the ecosystem for energy needs for heating and cooking purposes has come down in Bawan village with the arrival of cooking gas and electricity. Even so, there still is some degree of dependence on fuel wood. In the Supa Watershed area, the population continues to derive more than 75% of its fuel requirement from different resources from the ecosystem, with some innovative use of hydro-energy. In the Kushiro area, there is no dependence on the ecosystem to meet fuel requirements.
3. **Access to clean water:** This has been one of the most severely compromised services to the Bawan village. The Kahayan River has become unfit for consumption due to pollution from agricultural and illegal mining activities. The villagers travel around six kilometers to a natural spring to collect water for household purposes. The slide started from the late 1960's with the issue of private forest concessions for logging. Increased forest degradation, and water, increase in pollution from fertilizers and chemicals from farm activities contributed to a noxious situation. Conversely, in the Supa Watershed area, access to water and water quality were purposively improved through various water augmentation programmes. In the Kushiro Watershed area in Japan, the population has been chiefly dependent on water distribution services provided by the government since the last 50 years, which however is dependent on the Kushiro River water from the ecosystem.
4. **Health security:** In Bawan village, health security is ensured through a mix of traditional and modern therapeutics. The traditional system of medicine prevalent among the population is still actively patronized, indicating high dependence on resources within the ecosystem for health care. In fact, the traditional healers in the region are perhaps the most sought after service providers in the region, with earnings about four times higher than other production related livelihood activities. Both in Supa and Kushiro watersheds, such practices are no longer popular, and the population depends on mainstream hospitals or health clinics for health care. Even so, in Supa area, there is a limited degree of use of traditional medicine, and for this purpose, some natural resources are accessed from the ecosystem.
5. **Traditional activities and value added activities:** About 80% of total livelihood activities in Bawan village are traditional in origin and depend highly on ecosystem services. These include farming of crops such as Rice, Corn, vegetables and fishery related activities; along with plantations such as Rubber and Rattan. Of these, all activities that enter the local

market are profitable (Rice-with a net gain of around USD 163 per hectare[28]; fish- 3 USD per kilogram (less than 30 kg per harvest); Rubber- provides an income of 25 USD each harvest from a hectare (upto 300 Ha); Rattan- 9USD per ton (upto 30 tonnes) per three years; Timber – around 220 USD per cubic metre). However, although the percentage of profitable traditional activities (to total number of activities) is around 65 per cent, in real monetary terms they do not significantly drive the local economy. It bears noting that such activities continue to be a way of life for the majority of people, even if the returns only supplement other sources of income. Furthermore, most of the production from these activities is consumed for own purposes, or sold to neighbors without a profit motive. Commercial products such as Rattan and Rubber latex sheets are sold to agents, who later sell them to bigger traders and are ultimately traded in export markets. While the population does not derive a substantial share of the final price, it receives more than 50% of the price received by the next agent in the supply chain. However, in the mosaic of income flows into the economy, a significant share comes from income from off-site employment in government institutions, a major contributor to the local economy. In the Supa Watershed area in Yunnan, the number of traditional activities has declined to about 30 % of all activities, and proportion of value added activities to total activities is about 50% (which is higher than in earlier period), indicating that the region is primarily driven by income derived from activities not directly linked to the ecosystem. In Kushiro, except for some limited agriculture and farming activities, there is no dependence of the population on any traditional activity for securing their livelihoods. However, the region is home to a successful milk processing facility that derives its milk and several related resources from the farming activities and from the ecosystem. Although, this is not the major source of income for the area, both milk and butter and cheese products are marketed to distant urban markets. It is also expanding nature- tourism activities that bring in some tourist revenue. These again do not significantly drive the economy.

6. **Cultural dependence:** In Bawan, the people continue to have a high dependence on ecosystem for meeting their various spiritual and cultural needs. This is clear from the continued existence of sacred areas that are well governed and maintained, and from the conservation of educational forests initiated by research organizations in the area. Such areas, as is clear from the attached PRA map (Fig 4), also show high diversity of plant and animal species.

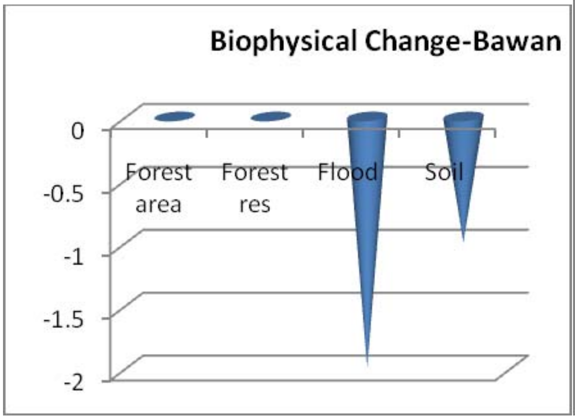
   In Supa watershed area, although sacred areas have been present, they are not actively governed or maintained. While this has remained unchanged, implying that the population derives same level of utility now as before, it also implies that the dependence of the people on the ecosystem for cultural and spiritual reasons has not been significant over the last 50 years. In the Kushiro area, since the 1980s, protection of natural areas, especially the wetland areas, has been encouraged to promote tourism. This has improved efforts to govern such spots for recreational purposes. These changes and dependencies are illustrated in Tables 4,5, 6 and Figures 6,7,8,9.

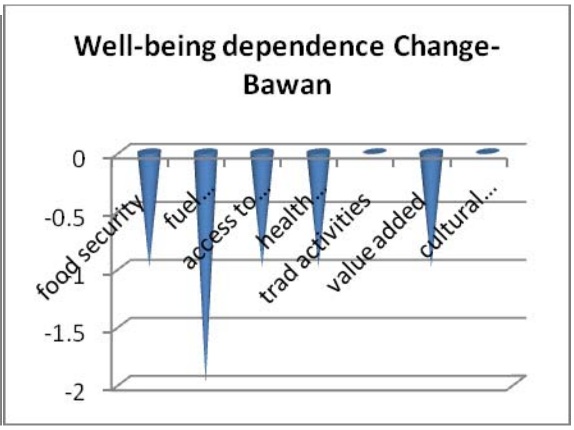
[28] At exchange rate of 1 USD = 9015 Indonesia Rupiah (as on July 26th 2010 from www.xe.com)

Table 4: Human well being dependence on Ecosystem services in Bawan (Indonesia)

Indicator	**Now**	**Before**	**Change**	**Remarks**
food security	2	2	0	
fuel sufficiency	0	2	-2	
access to clean water	1	2	-1	
health security	1	2	-1	
trad activities	2	2	0	
value added	1	2	-1	Although the economy is still driven by value added activities (from both traditional and new activities) from within the ecosystem, its role is subsumed by higher monetary returns from employment in other services
cultural dependence	2	2	0	Still high, as spiritual connectedness to sacred sites and resources still high

Fig 6: Changes to biophysical and well-being dependence (Bawan)





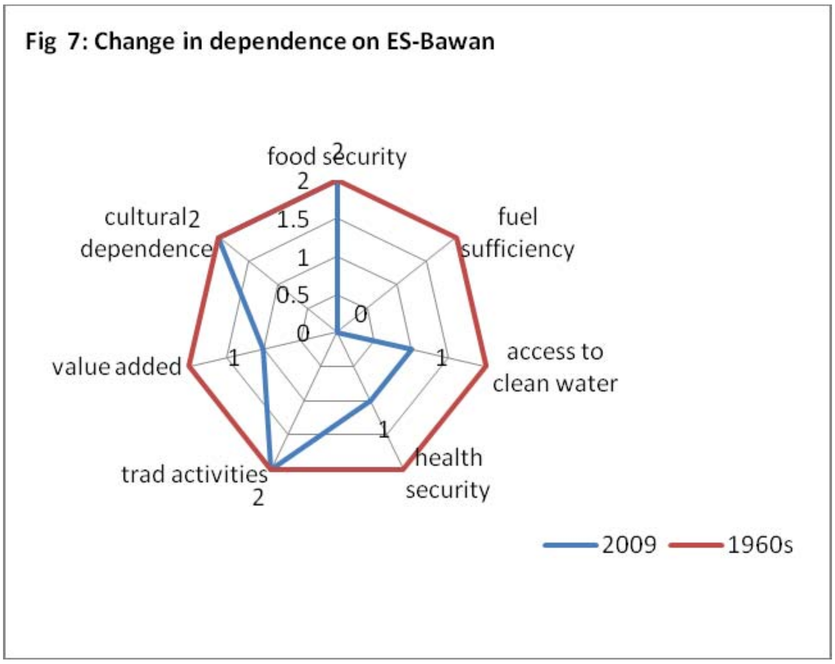


Table 5 Human well being dependence on Ecosystems - Supa Watershed (China)

Indicator	Now	Before	Change	Remarks
food security	2	2	0	Dependency is still high, although trend is decreasing
fuel sufficiency	2	2	0	Dependency is still high
access to clean water	2	1	1	Dependency high and ameliorated
health security	-2	0	-2	Dependency low and reducing
trad activities	1	2	-1	Dependency reducing
value added	1	0	1	Dependency reducing, as number of livelihood activities based on ecosystem services declining
cultural dependence	1	1	0	Infrequent use of cultural sites

Fig 8: Change in dependence on ES - Supa watershed

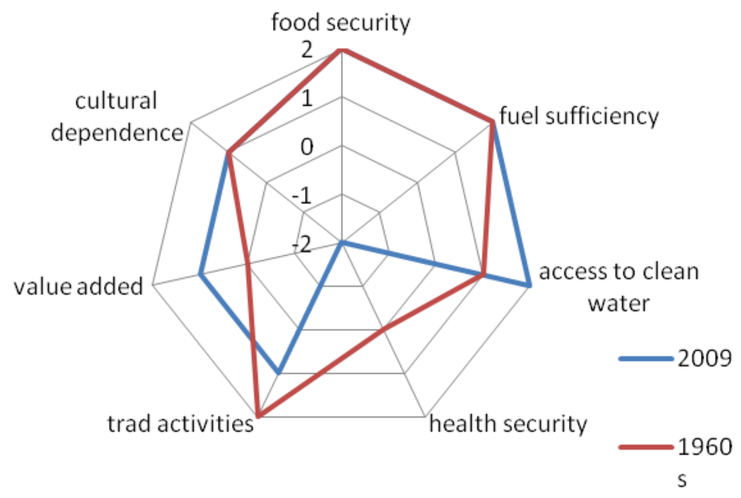
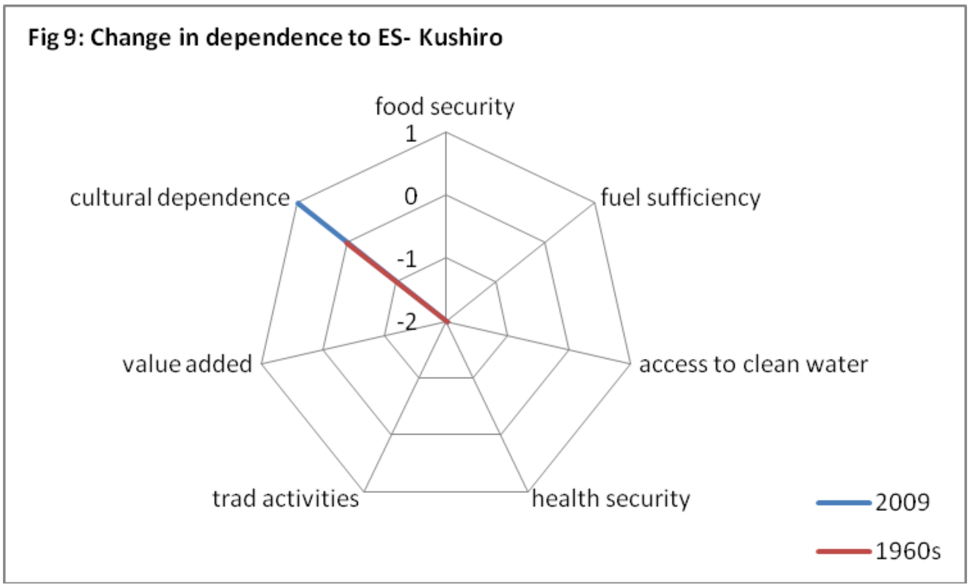


Table 6 Human well being dependence on Ecosystems - Kushiro Watershed (Japan)

Indicator	Now	Before	Change	Remarks
food security	-2	-2	0	Since the 1960s the population has been purchasing food from the market since well integrated with mainstream distribution systems, and with transportation systems (air, land and water) that increased imports
fuel sufficiency	-2	-2	0	Low fuel sufficiency, and totally dependent on imported oil
access to clean water	-2	-2	0	Totally dependent on water distribution systems
health security	-2	-2	0	Have depended since 1960s on mainstream dispensaries and village medical office and city hospital
trad activities	-2	-2	0	Some cattle raising is practiced although not considered a traditional activity, and some limited farming
value added	-2	-2	0	A successful milk processing unit is in place; however, in monetary terms this forms less than 10% of total livelihood activities in the region
cultural dependence	1	0	1	Emphasis for nature conservation, that began in a small scale among farmers during 1960s and became a policy between the 1970s and 1980s encouraged better maintenance of areas for recreational purposes



Comparison of changes to Biophysical characteristics of ecosystem with changes to human well-being

The Measurement of changes varies from a positive to negative scale. The interpretations for changes between biophysical and human well being indicators are given in Table 7

Table 7: Implications for changes between biophysical and human well being indicators

Biophysical change	Well being dependency change	Implications	Remarks
'0'	'0'	'0' indicates maintenance of status quo as before, whether low or high dependency. In the case of biophysical change, it indicates that the status of the parameter is at an intermediate level, requiring urgent action.	The interpretation of '0' values needs careful attention, and hence it is important to read it along with visual analytical tools viz. spider diagrams/ radar graphs that illustrate the path of changes taken for each characteristic.
Positive	Positive	Indicative of ideal situation representing optimum or near-optimum trade-offs.	
Positive	Negative	Indicates low exploitation of ecosystem services, and dependency on the	

		ecosystem for meeting well-being needs is low. It also indicates imported externalities, in conditions where the ecosystem is not disturbed to meet various requirements as they come from external ecosystems.	
Negative	0 to positive	Implies unsustainable use, and that degradation is ongoing	
Negative	Negative	Indicates degradation of both socio-economic and ecological systems	

Considering the changes to biophysical and human well being dependence, in *Bawan,* dependence of population on the different ecosystem services continues to be high. Traditional activities are still thriving although their productivities are on the decline; access to clean water has been highly restricted due to pollution of the river from various activities including logging and farming-related; in *Supa watershed*- traditional activities have reduced, value added activities have increased and access to clean water has increased; and in *Kushiro* there is not much change between the periods indicating early integration into external markets and consumption from embedded ecosystems imported from elsewhere. In Kushiro, is noteworthy that the changes had been so complete, that the respondents actually did not have much recollection of being part of food production activities before the 1960s. The preceding graphs capture vividly these changes (Figs 6, 7, 8, 9). Each of these situations requires multi pronged efforts to either maintain or adopt measures to optimize trade-offs between conservation and development goals. And, development goals would have to be sensitive to local inclinations to use products and services from immediate and familiar ecosystems – which is the idea behind participatory planning. The use of such indicators as described in the paper enable a snapshot view of such changes in both natural and social realms, and in turn facilitate planning and implementation of policies and practices on land use to ensure optimization to the maintenance of key indicators.

3.2 RESILIENCE

The growing body of research in managing complex ecological, social and economic systems (or termed socio-ecological systems) clearly identifies that this requires a system approach, with a need to focus on key components of a dynamic (The Resilience Alliance, 2007). This would enable developing strategies that would help buffer unexpected change or shocks and allow sustainable flow of goods and services (The Resilience Alliance, *ibid*). Such resilient systems ought to cover the natural (environments) and the social contexts enabling an ecosystem and the population using the ecosystem to be able to proactively adapt to changes and/or disturbances. Here, we try to understand how predisposed the ecosystems (in the case studies) are to being resilient. Hence, the focus is on factors that facilitate resilient systems both in natural and social systems.

3.2.1 Natural Resilience

Resilience of natural endowments or productive resources would be dependent, at a minimum, on the following factors: the continued availability of natural productive assets to enable production; sustained growth in productivity of crops; well-developed norms for governance of natural resources and ecosystem and adherence to these norms; policies that enable obtaining certainty of tenure rights and those that encourage land use to enjoy various ecosystem services. The following indicators were defined to capture changes to these factors of resilience of the natural systems in the study areas for the time period of 50 years.

Indicator	Scores
1. Availability of natural productive Assets	*1. If >75% (2)* *2. If 50-75% (1)* *3. If 25-50% (0)* *4. If 10-25% (-1)* *5. If <10% (-2)*
2. Change in productivity of different activities (No. of productive activities whose productivity has reduced / total number of productive activities): Here all productive activities based on the ecosystem are treated equally, as the emphasis is to see how productivities are changing across them, and therefore to the ecosystem. Data was obtained from PRA interviews, where the participants discussed on their livelihood activities and changes to the costs , returns and yield of each. The ratio is based on a count of activities whose yields have reduced over the time period.	*1. If > 0.75 – significant degradation (-2)* *2. If 0.5 - .75 – high degradation (-1)* *3. If 0.25- 0.5 (0)* *4. If 0.1 – 0.25 –low degradation (1)* 5. *If <.1 – very low degradation* (2)
3. Existence/ Adherence to governance norms: (obtained from PRA interviews). It has been shown that the prevalence and practice of well established norms to manage and govern natural systems contributes to conservation and sustenance of the systems (Suneetha and Pisupati, 2009).	*1. If existing in detail for broad categories of resources and adhered to fully (2)* *2. If existing in detail for broad categories of resources and partially adhered to (1)* *3. If existing for few categories and adhered to (0)* *4. If existing for few categories and not adhered to (-1)* *5. If not existing (-2)*
4. Policies on tenure rights and ownership: It has been well acknowledged that well-	*1. Very well defined tenure rights that includes acknowledgement of customary norms of*

defined tenure rights, include recognition of customary use rights, provide a strong incentive enabling a higher likelihood to foster conservation (Clover and Erikson, 2009).	*rights (2)* 2. *Somewhat clear (when rights are present, but shared or subsumed with other stakeholders) (1)* 3. *No tenure rights (0)* 4. *Partial loss of tenure rights that existed before (-1)* 5. *Removal of tenure rights (-2)*
5. Policies on land use: As is evident, the condition of ecosystems and their capability to provide services are affected by policy decisions. The influence of policies on the study areas over the time period is therefore captured as a factor to facilitate natural resilience.	1. *Policies that promote total changes that negatively affect all services of ecosystem (-2)* 2. *Promote changes that negatively affect few services of ecosystem (-1)* 3. *Some change to ecosystem that does not affect essential services from ecosystem (such as provisioning, regulating functions)* 4. *Promotes some changes to ecosystem that enables improvement of some services of ecosystem (1)* 5. *Promotes changes that enables improvement to all services of ecosystem (2)*

Table 8: Resilience related indicators for biophysical resources in Bawan village, Supa and Kushiro watersheds (1960-2009)

Indicator	Bawan	Supa	Kushiro	Remarks
Availability of productive assets	2	2	2	All regions continue to have more than 75% of their productive resources
Change in productivity of different activities	-1	1	NA	In Bawan, there has been a decline in productivity of crops, such as Rice, Corn, etc and of fish harvests resulting in economic losses at a minimum of 22 to 25 % from the earlier period, nothwithstanding loss of opportunities to pursue other alternative activities ; in Supa, productivity has increased; while in Kushiro, most activities are no longer patronized, although soil productivity is considered to be good.
Existence /adherence to governance norms	0	0	0	In Bawan, norms exist as before for a broad category of resources and are still adhered to; in Supa, norms exist only for few categories as before and are adhered to; in Kushiro-such norms are not common between the time periods
Policies on ownership/tenure rights	1	1	2	Ownership rights in both Bawan and Supa are primarily usufructory in nature, and are subject to changes in

				implementation policies; while in Kushiro-tenure rights are clearly defined between the different stakeholders
Policies on land use	-1	1	-1	In Bawan, state policies on intensive cultivation and others related to land use resulted in reduction in capacity of ecosystem to provide certain services; in Supa, land use policies enabled restoration of certain ecosystem services while in Kushiro, certain services were irrevocably changed to provide for infrastructural development

3.2.2 Socio-economic Resilience

A resilient community or population has been defined as one that is capable of adapting quickly to change (Callaghan and Colton, 2008). In the context of this study, resilience in terms of socio-economic factors is defined in terms of strategies undertaken to mitigate risks from natural and economic shocks to the people in the ecosystem. All the data was collected from PRA discussions. The different indicators identified for this purpose include:

Indicator	Scores
1. **Number of activities:** refers to improvement in economic alternatives that serve as a buffer in the event of natural or economic shocks to any acitivity.	1. *increase in the number of alternatives or if there are three or more alternatives (2);* 2. *increase in the number of alternatives and if there are 2 alternatives (1);* 3. *no alternatives/ single activity (0);* 4. *decline in number of alternatives (-1);* 5. *sharp reduction in alternatives/ no activity (-2)*
2. **Savings :** refers to improvement in various ways of saving such as bank accounts and other formal and informal mechanisms .	1. *much improvement if there are several mechanisms(2);* 2. *moderate improvement if there is at least one mechanism (1);* 3. *no savings (0);* 4. *moderate reduction in savings if a few mechanisms do not function any more(-1);*

	5. *sharp reduction in savings if all mechanisms have been removed (-2)*
3. **Insurance:** refers to improved access to various schemes that protect against different kinds of risk to life, property and collateral	1. *much improvement, i.e., access to several schemes such as for crops, life, etc.;more than two schemes (2);* 2. *moderate improvement, if access to a single scheme (1);* 3. *no schemes (0);* 4. *moderate decline, if., few schemes become defunct (-1);* 5. *sharp decline, if, several schemes become defunct (-2)*
4. **Equity :** Non-discrimination and equity among the different stakeholders in a context is necessary for peaceful co-existence. Furthermore, it allows consensual decision making for the common good of the population and to the environment they dwell in. The following indicators were defined to capture equity within the study areas.	
A. Share in prices: attempts to capture equity in market transactions at least with next level in the supply chain of the commodity.	1. *If >50% share of next agent price(2)* 2. *25-50% (1)* 3. *10-25% (0)* 4. *5-10% (-1)* 5. *< 5 % (-2)*
B. Access Equity among stakeholders: attempts to capture rights to access different resources among different stakeholders (different groups) within a community, and is defined by improvement in the degree to which a community is inclusive of all its members in providing access to resources	1. *all members have equal access(2);* 2. *most members have equal access(1);* 3. *some members have access and is better than earlier period(0);* 4. *reduction in members who have access from earlier period (-1);* 5. *sharp decline, i.e., no representation* of different stakeholders (-2);
C. Equal rights to occupy leadership positions : attempts to capture rights to representation among different stakeholders within a community.	1. *all members have equal rights(2);* 2. *most members have equal rights(1);* 3. *some members have rights and is better than earlier period(0);* 4. *reduction in members who have rights from earlier period (-1);* 5. *sharp decline, i.e., no representation of different stakeholders (-2);*
D.Standard of living of all members: considers the capacity of different members of the population to meet their basic aspirations.	1. *>75% of members are able to meet their aspirations (2)* 2. *50-75% of members are able to meet their aspirations (1)* 3. *25-50% (0)* 4. *10-25% (-1)* 5. *<10% (-2)*

Institutional Linkages

Linkages to various institutions could enable communities to build capacity, meet their needs, undertake pro-active measures related to production, marketing and conservation and build networks with broader communities outside of their sphere of influence. During the PRA exercise, discussions centered on institutional linkages were the most animated, especially in regions like Bawan where land use decisions were based on several loosely defined policies of the government that allowed varied interpretations and conflicts due to ill defined hierarchies among the village and district leadership. However, in the course of time, these institutional linkages have also evolved structures that enable the residents to achieve certain objectives. Broadly, five categories of institutions were identified, and their roles in the well being of the population are as follows:

a. Partnerships (eg. Linkages with NGOs, marketing agencies, government, co-operatives) :

    1. Bawan: with government and research centers very high, that enabled establishment of educational forests, and easy access to information, and better prices for some products. To some extent, this also led them to excessively adopt high input technologies promoted by the government, with deleterious effects to their lands and waters

    2. Supa: with government extension services providing them information and support;

    3. Kushiro: with government extension services and Non-government organizations that promoted campaigns to preserve nature.

b. Infrastructure for communication: In all 3 regions, road and telephone facilities have been developed. Road networks are expanding, and are a constant bone of contention between concerns of conservationists and calls for better facilities to enable faster and comfortable communication with main town centers. Prevalence of good communication facilities enables quicker responses to any disturbances.

c. Banks : are present in all three regions, and has facilitated improved access to credit. To some extent, it has also enabled re-investment opportunities.

d. Hospitals: are now available nearby, and believed to have improved health access in all three regions. However, in Bawan, as earlier stated, traditional healers and system of medicine is still widely patronized.

e. Educational : educational opportunities have increased, and in all three regions, there has been an increase in the number of graduates. In Bawan, they often seek opportunities in government or research sectors, which lets them stay in some proximity to the village. This is also because of the prevalence of a fairly strong affinity to their culture and practices, although to some extent this is going down over the generations. In the case of Kushiro and Supa watersheds, the educated workforce has shown a preference to move further away from the ecosystems. An increase in educational facilities has allowed the residents to seek livelihoods outside of the ecosystem.

Table 9: Resilience of socio-economic parameters in three sites

Indicator	Bawan	Supa watershed	Kushiro watershed	Remarks
No. of livelihood related activities	2	2	2	All 3 regions have several livelihood activities that to some extent shields them from natural and economic shocks in one sector
Savings	1	1	2	All regions have different ways of saving, with many options being explored by Kushiro residents
Insurance	1	1	2	Residents in Bawan and Supa have limited access to insurance schemes. Kushiro residents insure for life, activities, equipment, etc.
Share in prices	2	2	2	Residents in all 3 regions get between 50 - 60 % of the price paid by next agent
Access to resources	2	2	2	Now, in all 3 regions there is equity in access to resources especially common pool resources, subject to governance norms
Access to leadership	1	1	2	Access to leadership in Bawan and Supa is restricted to certain groups, while in Kushiro, it is open to anybody who is elected through a democratic process
Standard of living of all members	2	2	2	In all 3 regions, most of the residents have similar standard of living

Fig 6: Resilience of biophysical parameters in 3 study areas

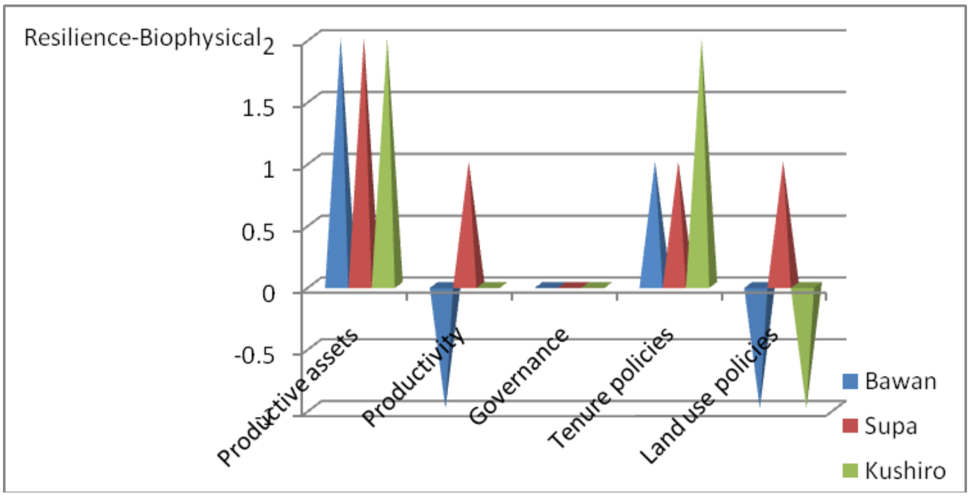
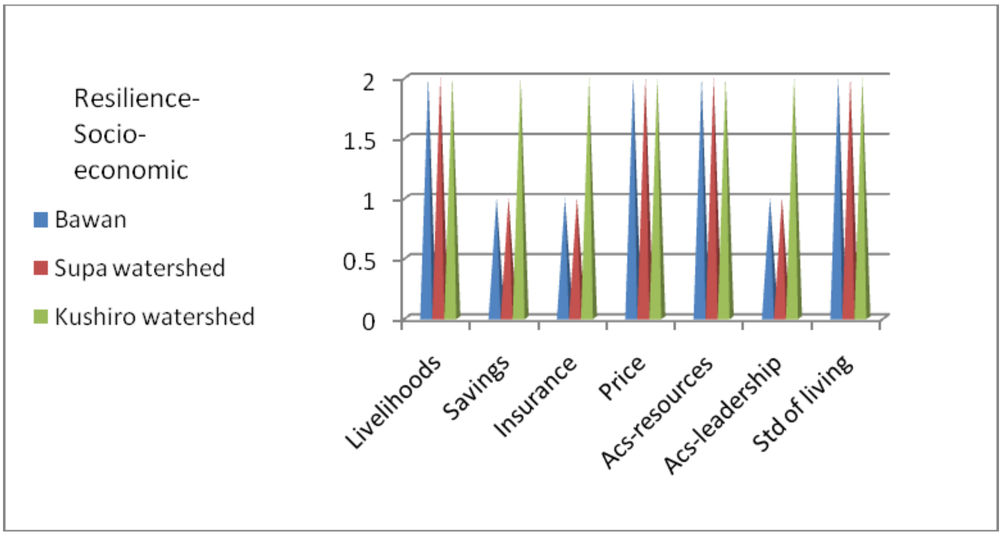


Fig 7: Socio-economic resilience of 3 study areas



Implications

Resilience-Natural	Resilience-Socio-economic	Implications
0	0	'0' would indicate impending change and an urgent call for action
positive	positive	High resilience of natural and socio-economic parameters indicating high adaptive capacity
Negative	Positive	Exploitation of natural resources although social systems have developed capacities to adapt to disturbances
Positive	Negative	Implies possible underutilization of natural systems Very low development of adaptive capacities of the population
Negative	Negative	Capacities of both socio-economic and natural systems to adapt and regain homoestasis in the event of a disturbance severely hampered

It is noteworthy that all three regions almost score uniformly on all indicators for socio-economic resilience, although their 'natural' resilience is very different. In a way, this is reflective of the development path that societies adopt, irrespective of ecosystem backgrounds and differences of natural endowments. There are some variations in definitions of different indicators of resilience between the study areas. For instance, Bawan and Supa watershed areas are still characteristic of production-based local economies, where concepts of savings and insurance are not pre-defined by modern monetary concepts. In Bawan village, savings are generally invested in long term asset based activities such as livestock, rubber or rattan plantations, purchase of transport equipment and towards educational expenses of children. This works out to about 25 % or their total expenditure. It is not necessarily saved completely as money in bank or as cash. Whereas, Kushiro is a typical case of a rural area that has been fully integrated with mainstream systems and therefore prescribes to different scales of planning and distribution. In terms of natural resilience, of the three areas, Supa watershed appears to be the most resilient, primarily driven by policies that seek to enhance the ecosystem – including policies on hydro-energy management and increasing forest area. The social, economic and political pressures in each region have been varied, and while it may be presumptuous to compare between them, there definitely are lessons that can be derived amidst them. From the figures (Figure 6 and 7) it is clear that policy drivers have a critical role to play in fostering resilience of ecosystems and communities dependent on them. Ad-hoc policies driven by short term concerns of income augmentation often lead to environmental and subsequent wellbeing catastrophes, as is clear from the Bawan case. This is further accentuated when the population continues to be highly dependent on the ecosystems, as their ecosystem-based activities build on policy directives, which is often not in line with their traditional governance mechanisms. On the other hand, as seen in the Kushiro case, non-use of ecosystems could result in high levels of biophysical resilience with wellbeing needs being met from external sources or imported from external ecosystems. Its impact on ecosystem health balance on a regional scale certainly merits further research. This scenario would in all high likelihood be similar to consumption trends in urban centers. Analysing the flow of ecosystem services and goods in consumption centers and their impacts on providing ecosystems, would help develop appropriate mechanisms of equitable pricing and production of goods and services that would enable maintenance of quality and vitality of ecosystems.

4. Conclusions

The research enables a comprehensive chalking of the paths taken by the different actors in the study areas to respond to different priorities. Reading the maps generated from the PRA exercise with the remote sensing maps provide several additional layers of information on land-use and quality. By using an indicator-based approach, the direction of changes to ecosystem and dependence of human well-being on immediate ecosystems can be compared at the same time. This can be useful to inform policy and provide inputs to practitioners on land use decisions. The research also served a social function, by rallying the stakeholders who participated in the multi-stakeholder PRA meetings to view challenges related to their wellbeing and their ecosystem holistically, and to strategize on proactive measures to address them. The positive feedback from the study areas reiterates conclusions of other authors for the need to adopt participatory tools in ecosystem valuation methods that would enable action to proceed from the results of research in a reasoned, deliberative and equitable fashion (Wilson and Howarth, 2002; Costanza and Folke, 1997. As noted by Farber *et al*(2002), such 'participatory democracy approaches" enable formulation of environmental policies in a decentralized manner, and also allow 'non-experts' to participate in such decisions.

The use of spatial maps validates the relevance and utility of diachronic observations of communities and other stakeholders directly dependent on ecosystems. At the same time, they can be used to strengthen local planning processes for the development of services in the ecosystem, of relevance to humans and nature. Such methods can hence act as a catalyst to a social process of co-ordinated action to address local issues of global relevance.

The utility of this research has also been in demonstrating that data obtained from objective sources (such as remote sensing maps), when integrated with more subjective data (from interviews and including perspectives of populations living within ecosystems) can provide rich details on changes to ecosystem, both in current time and over a historical timeline, what drives these changes in specific locations, and how it translates in terms of development priorities for the different stakeholders. The different case studies implicitly highlight the different kinds of trade-offs that can occur in use of ecosystem services. The scenarios range from a context where sub-systems within a rich ecosystem are severely damaged due to misplaced policies and human action, seriously incapacitating the rendering of various services whose marginal utilities continue to be high to the residing population (Bawan) ; to a context where despite the availability of a healthy ecosystem, a population would depend for most essential services to be provided from remote locations (Kushiro), indicating that the population still derives high utility from ecosystem services but while they are willing to pay a direct cost for these services, they are not inclined to bear the costs of working up the ecosystem to provide them the required services; and somewhat between the two, a context where proactive policies and actions at the ground level have striven to maintain and augment the environment and lives of dependent people through opting for a mix of deriving utilities from the surrounding and other ecosystems, and containing deleterious disturbances (Supa). Policy decisions related to land use have played a major role in shaping the current state of ecosystems in all three contexts, thereby implying the need for more informed decision making by decision makers.

The authors consider the analytical framework as a work in progress, noting that further refinements in defining indicators especially for changes to biophysical parameters are possible and required. Such an indicator based system allows simplification of technical data from remote sensing maps, and provides possibilities for integration with socio-economic data. This can be appealing to and easily molded into formats to communicate to non-specialist stakeholders about challenges to their well-being and ecosystems and identify solutions or at least avenues that can be explored to address them. For policy makers, it provides a simple depiction of the complexities involved in land use decisions, especially in ecosystems supporting diversities of life.

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Chapter 8

Mapping land-cover changes at the national level.

Wenbin Wu, Zhongxin Chen, Li Zhang, Peng Yang, Zhengguo Li, Jinqiu Zou

1.0 Introduction

Currently, the forestry sector is being considered an appropriate option for limiting green house gases (GHG) concentration in the atmosphere. Deforestation has a great impact on global or regional carbon emissions or uptakes, and is thus of concern to scientists and policy-makers around the world. Previous research on global carbon stocks showed that 55% of global net carbon flux during the period 1850-2000 is from tropical region due to forest cover changes (Achard et al. 2004). Meanwhile, it is also possible to mitigate climate change through conserving existing forests, expanding carbon sinks, substituting wood products for fossil fuels and reducing emissions from deforestation and degradation (known as the REDD mechanism). REDD is an instrument that could reward countries with carbon credits for preserving their forest cover. Under the recent initiative, known as Forest Carbon Partnership Facility (FCPF), 14 developing countries will receive grant support as they build their capacity for REDD through measure including establishing emissions reference levels, adopting strategies to reduce deforestation and designing monitoring systems (DeFries et al., 2007; Vogelmann et al. 2009). Therefore, understanding forest cover changes in tropical regions and its effects on net carbon changes is of great importance. This study aims to monitor forest cover changes and estimate the national net carbon changes during the period of 1990s-2000s in Southeast Asian using Thailand, Malaysia and Indonesia as case studies.

2.0 Methodology

This study focuses on the net carbon flux caused by deforestation and afforestation in Thailand, Malaysia and Indonesia over the period from 1990s to 2000s. Figure 1 shows the general structure of the research, which includes three sections: (1) data preparation and processing, (2) monitoring forest cover changes by using remote sensing, and (3) identifying driving forces of forest cover change.

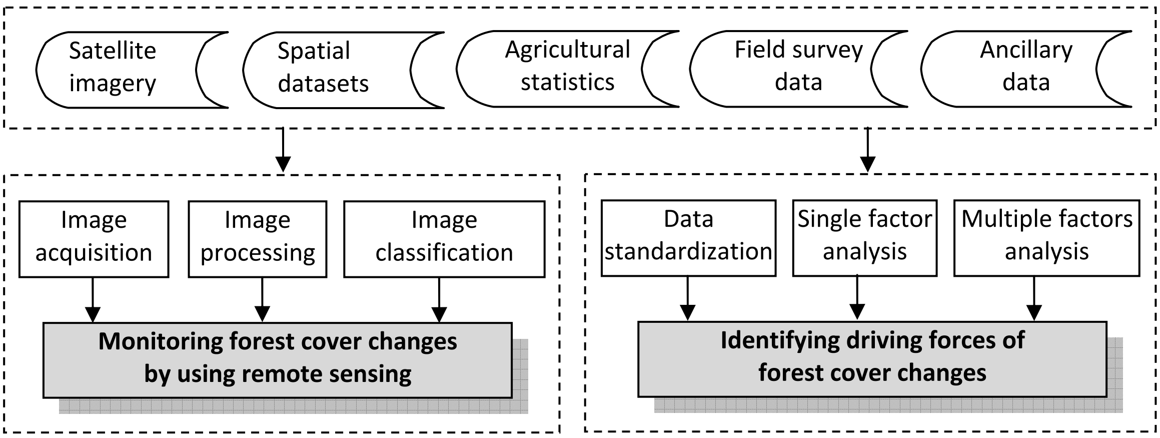


Figure 1. General structure of this study

2.1 Data Preparation and Processing

A very large amount of input data, including remotely sensed data and socio-economic data, were utilized in this study. Of these data, remotely sensed data were used directly for image classification so as to map and monitor the forest cover changes for the study region. The socio-economic data were used to link with the forest cover change maps to determine the major driving forces of forest cover changes.

Remotely sensed data

In this study, Landsat TM or ETM+ imagery at a 30 m spatial resolution for two time periods, i.e., 1990s and 2000s, were collected and acquired from Earth Science Data Interface, Global Land Cover Facility. Following is the detailed information for the data.

- Scene coverage: Path:99-132, Row:46-68
- Geo-location coverage: 90°E-160°E; 22°N-12°S
- Spatial resolution: 30 m

Figure 2 show the collected TM images for the 1990s and 2000s, respectively. In total, there are 186 scenes of TM downloaded for 1990s, and 189 scenes for 2000s, with the total file size of 131.7 GB.

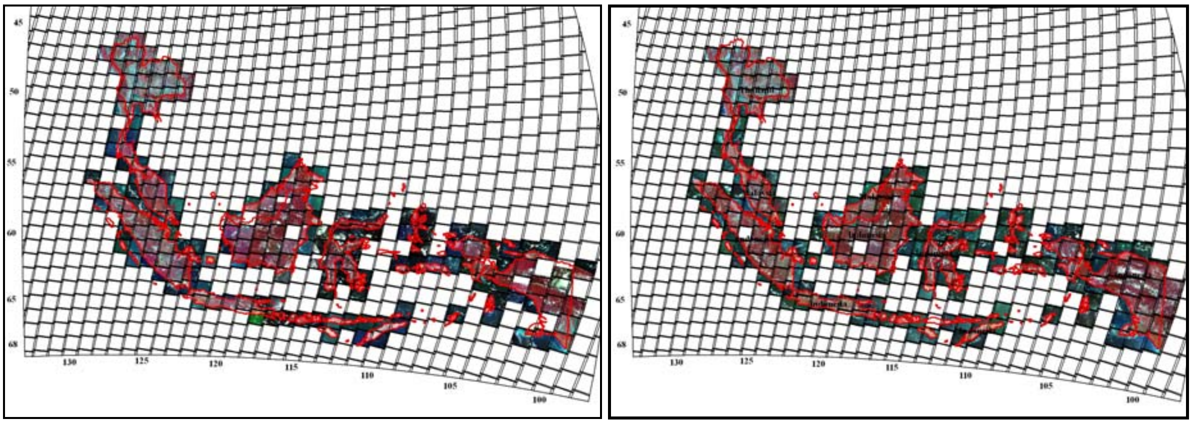


Figure 2. TM images for 1990s and 2000s

Figure 3, Figure 4 and Figure 5 are the downloaded TM images for Malaysia, Thailand and Indonesia for 1990s and 2000s, respectively.

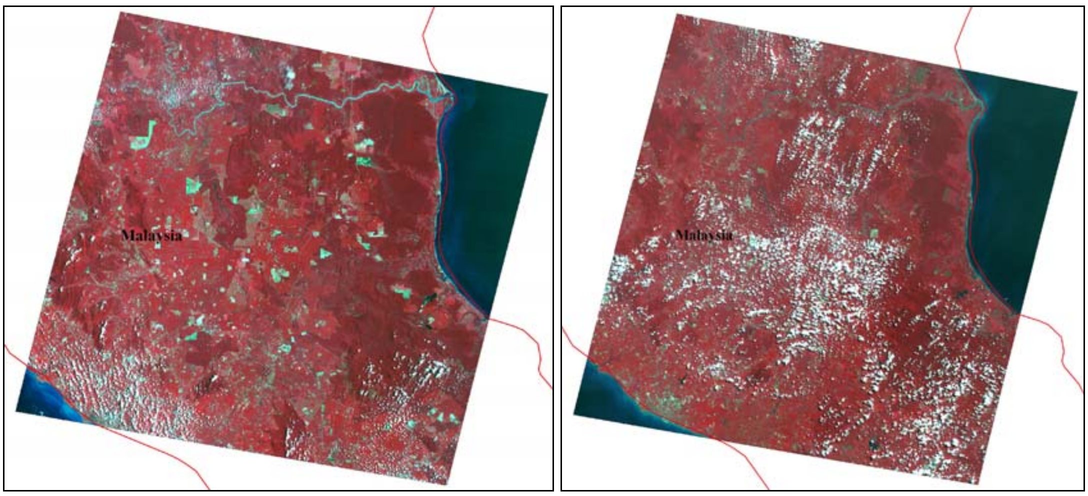


Figure 3. TM (Path:126/Row:58) for Malaysia

Left: acquired at 1990-09-07, Right: acquired at 2000-07-08

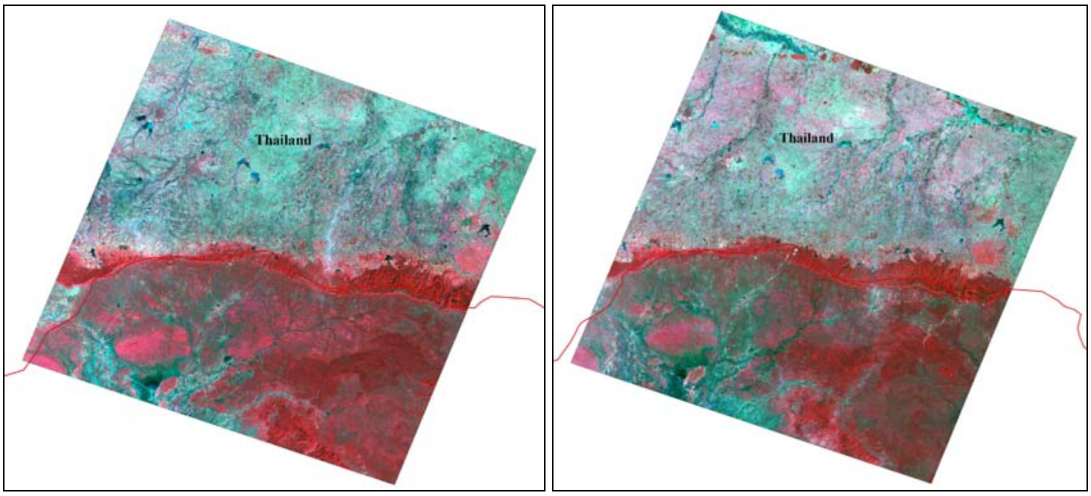


Figure 4. TM (Path:127/Row:50) for Thailand

Left: acquired at 1990-11-17, Right: acquired at 2000-11-04

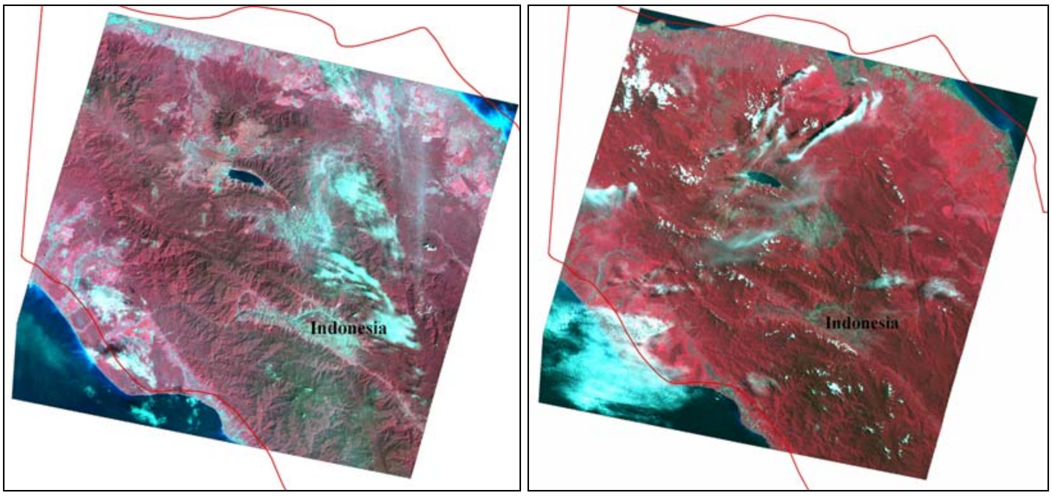


Figure 5. TM (Path:130/Row:57) for Indonesia

Left: acquired at 1990-01-06, Right: acquired at 2000-08-05

In addition to the TM data, some other remote sensed products listed in Table 1 were also used for image classification or validation.

Table 1. Five global land cover datasets

No.	Data name	Data source	Specification
1	UMD global land cover dataset	Maryland University (http://www.geog.umd.edu/landcover/1km-map.html)	Spatial resolution: 1 km Source image:1992/1993
2	IGBP-DISCover global land cover dataset	http://edcsns17.cr.usgs.gov/glcc/globe_int.html	Spatial resolution: 1 km Source image:1992/1993
3	MODIS global land cover dataset	Boston University (http://duckwater.bu.edu/lc/datasets.html)	Spatial resolution: 1 km Source image:2000/2001
4	GLC 2000 global land cover dataset	EU Joint Research Centre (http://www-tem.jrc.it/glc2000/)	Spatial resolution: 1 km Source image:1999/2000
5	MERIS GLOBCOVER	CNES, CNRS, IRD, Météo-France, and	Spatial resolution: 300m

	global land cover dataset	INRA (http://postel.mediasfrance.org/en/DOWNLOAD/)	Source image:2005/2006

Socio-economic data

Social-economic data such as population, GDP and timber consumption at national or province level, and some spatial datasets such as digital topographic map, road system map and settlement distribution map, were collected from CIESIN, IIASA, ESRI and FAO Statistics. Table 2 is the list of collected socio-economic datasets for this study.

Table 2. List of socio-economic datasets

No.	Data name	Data source	Specification
1	**Road accessibility**	**ESRI product digital chart of the world database (http://www.maproom.psu.edu/dcw/)**	**Time period:1993**
2	**Rural population density**	**Landscan Global Population Database (http://www.ornl.gov/sci/landscan/)**	**Time period:1998**
3	**Gridded population and GDP data**	**Austria International Institute for Applied Systems Analysis (IIASA) data center**	**Time period:2000**
4	**County-based urban and rural population**	**UN World Urbanization Prospects: The 2007 Revision (http://geodata.grid.unep.ch)**	**Time period:1980-2000**
5	**Global map of irrigated areas**	**http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/global_irrigation_map/index.html**	**Time period:1995 and 2005**
6	**FAO statistical database**	**FAOSTAT (http://faostat.fao.org/)**	**Time period: 1963 till now**

2.2 Monitoring forest cover changes by using remote sensing

We used Landsat TM data to map forest cover for two time periods, i.e., 1990s and 2000s. The resulting maps were then overlaid to produce the forest cover change map between 1990s-2000s. Two kinds of forest cover changes can be identified from land cover maps:

- A reduction in forest area which can happen through either of two processes. The first is anthropogenic deforestation, which is by far the most important. It implies that forests are cleared by people and the land converted to other uses, such as agriculture or infrastructure. The second is destruction of forests by natural disasters. When the area is incapable of regenerating naturally and no efforts are made to replant it, the forests may reverts to other land.
- An increase in forest area can also happen in two ways: either through afforestation, i.e. planting of trees on land that was not previously forested, or through natural expansion of forests, e.g. on abandoned agricultural land.

Where part of a forest is cut down but replanted (reforestation), or where the forest grows back on its own within a relatively short period (natural regeneration), there is no change in forest area.

2.2.1 Forest cover classification scheme

This study followed the FAO Land Cover Classification System (LCCS) and IGBP classification to define forest cover types for our study. The LCCS is a comprehensive, standardized a priori classification system, designed to meet specific user requirements, and created for mapping exercises, independent of the scale or means used to map. Land cover classes are defined by a combination of a set of independent diagnostic criteria - the so-called classifiers - that are hierarchically arranged to assure a high degree of geographical accuracy. Because of the heterogeneity of land cover, the same set of classifiers cannot be used to define all land cover types. The hierarchical structure of the classifiers may differ from one land cover type to another.

Table 3 shows the land cover classification scheme applicable to this study.

Table 3. Land cover classification scheme for this study

Forest types	Land cover types	Class id
Forest cover	Evergreen needleleaf forest	1
	Evergreen broadleaf forest	2
	Deciduous needleleaf forest	3
	Deciduous broadleaf forest	4
	Mixed forest	5
Non-forest cover	Shrublands	6
	Savannas	7
	Grasslands	8
	Croplands	9
	Urban and built-up	10
	Unused lands(Permanent wetlands, Snow and ice, permanent barren or sparsely vegetated, water bodies	11

2.2.2 Experiment on image classification

The classification method used is of great importance for final results be it the land cover or the land-cover change maps and their accuracies. Since there are more than one hundred of images to be processed and classified, it is necessary to select a region to test the method and choose the appropriate algorithm before the large amount of images enters into the classification stage (Hais et al. 2009). Thus, we selected one study area in Southwest China for image classification experiment (Figure 6).

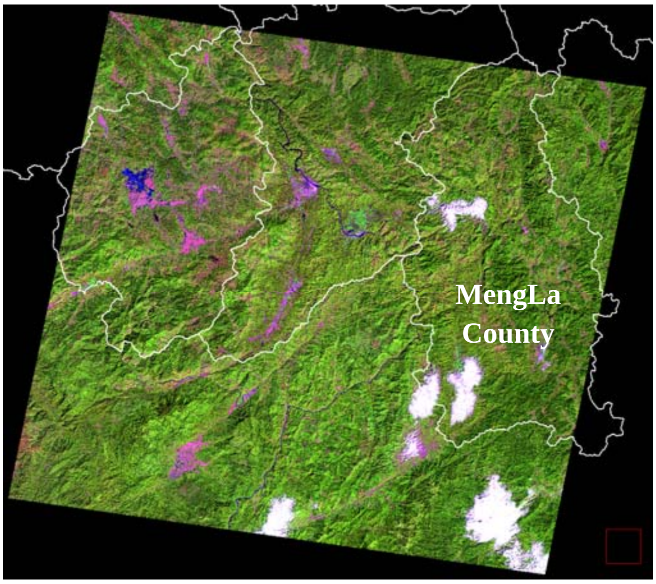


Figure 6. Location of study area of MengLa county

From 11th to 17th, January, fieldwork was carried out in MengLa to collect identify spectral information and collect non-spectral information and other ancillary data so as to gain the prior knowledge about forest types and distribution and location. Some forest training samples as well as other land cover types were collected and geo-located by using GPS. Figure 7 shows the locations of sampled site in MengLa county, whereas Figure 8 and Figure 9 depict the information table used and the data collected in the fieldwork.

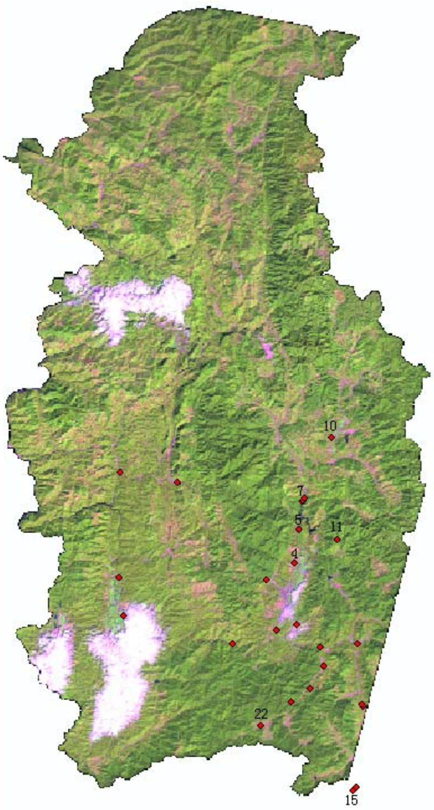


Figure 7. Sampling sites in Mengla county

云南勐腊县森林资源类型调查表

样点编号：…………………… 调 查 人：……………………

调查日期：___年___月___日___时___分 调查地点：___县___镇（乡）___村

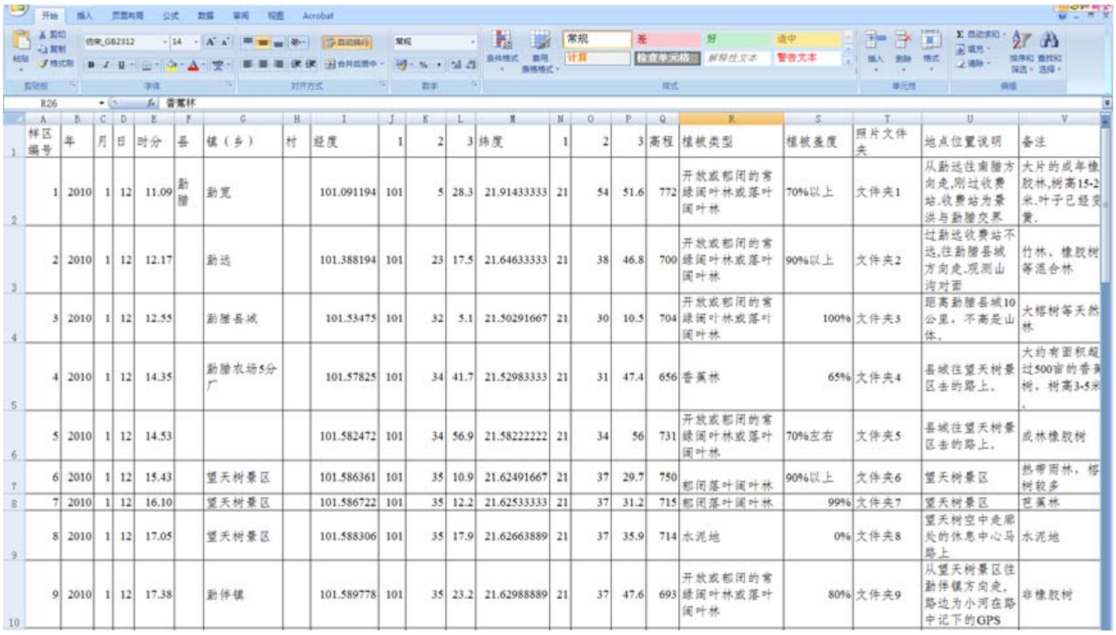
GPS 定位（Geolocation）				备 注
编号	东经 LONG	北纬 LAT	高程（M）	
1				
2				
植被类型				
植被盖度				
照片编号				
社会经济信息调查				

森林资源类型代码表

代码	英文名称	中文名称
40	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest(>5m)	开放或郁闭的常绿阔叶林或落叶阔叶林
50	Closed (>40%) broadleaved deciduous forest (>5m)	郁闭落叶阔叶林
60	Open (15-40%) broadleaved deciduous forest (>5m)	开放落叶阔叶林
70	Closed (>40%) needleleaved evergreen forest (>5m)	郁闭常绿针叶林
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	开放的落叶针叶林或常绿针叶林
91	*Open (15-40%) needleleaved deciduous forest (>5m)*	*开放落叶针叶林*
92	*Open (15-40%) needleleaved evergreen forest (>5m)*	*开放常绿针叶林*
100	*Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)*	*郁闭或开放的针阔混交林*
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	林地或灌丛/草地的镶嵌体
120	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	草地/林地或灌木林的镶嵌体
130	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	郁闭或开放的灌木林
131	*Closed to open (>15%) broadleaved or needleleaved evergreen shrubland (<5m)*	*郁闭或开放的常绿落叶灌木林或常绿针叶灌木林*
134	*Closed to open (>15%) broadleaved deciduous shrubland (<5m)*	*郁闭或开放的落叶阔叶灌木林*
153	*Sparse (<15%) trees*	*稀疏林地*

Figure 8. Information table used in fieldwork

Figure 10 are some photos of different land cover types taken during fieldwork. Figure 11 is the general flowchart of knowledge-based classification subsequent to field survey.



样区编号	年	月	日	时分	县	镇（乡）	村	经度	1	2	3	纬度	1	2	3	高程	植被类型	植被盖度	照片文件夹	地点位置说明	备注
1	2010	1	12	11.09	勐腊	勐宽		101.091194	101	5	28.3	21.91433333	21	54	51.6	772	开放或郁闭的常绿阔叶林或落叶阔叶林	70%以上	文件夹1	从勐远往南腊方向走,刚过收费站.收费站为景洪与勐腊交界	大片的成年橡胶林,树高15-2米.叶子已经变黄.
2	2010	1	12	12.17		勐远		101.388194	101	23	17.5	21.64633333	21	38	46.8	700	开放或郁闭的常绿阔叶林或落叶阔叶林	90%以上	文件夹2	过勐远收费站不远,往勐腊县城方向走.观测山沟对面	竹林、橡胶树等混合林
3	2010	1	12	12.55		勐腊县城		101.53475	101	32	5.1	21.50291667	21	30	10.5	704	开放或郁闭的常绿阔叶林或落叶阔叶林	100%	文件夹3	距离勐腊县城10公里，不高是山体。	大榕树等天然林
4	2010	1	12	14.35		勐腊农场5分厂		101.57825	101	34	41.7	21.52983333	21	31	47.4	656	香蕉林	65%	文件夹4	县城往望天树景区去的路上。	大约有面积超过500亩的香蕉树，树高3-5米。
5	2010	1	12	14.53				101.582472	101	34	56.9	21.58222222	21	34	56	731	开放或郁闭的常绿阔叶林或落叶阔叶林	70%左右	文件夹5	县城往望天树景区去的路上。	成林橡胶树
6	2010	1	12	15.43		望天树景区		101.586361	101	35	10.9	21.62491667	21	37	29.7	750	郁闭落叶阔叶林	90%以上	文件夹6	望天树景区	热带雨林，榕树较多
7	2010	1	12	16.10		望天树景区		101.586722	101	35	12.2	21.62533333	21	37	31.2	715	郁闭落叶阔叶林	99%	文件夹7	望天树景区	芭蕉林
8	2010	1	12	17.05		望天树景区		101.588306	101	35	17.9	21.62663889	21	37	35.9	714	水泥地	0%	文件夹8	望天树空中走廊处的休息中心马路上	水泥地
9	2010	1	12	17.38		勐伴镇		101.589778	101	35	23.2	21.62988889	21	37	47.6	693	开放或郁闭的常绿阔叶林或落叶阔叶林	80%	文件夹9	从望天树景区往勐伴镇方向走,路边为小河在路中记下的GPS	非橡胶树

Figure 9. Detailed information about the sampling sites

Figure 10. Photos of different land cover types

Upper left: closed evergreen broadleaved forest; Upper right: open to closed evergreen or deciduous broadleaved forest; Lower left: banana yard; Lower right: croplands

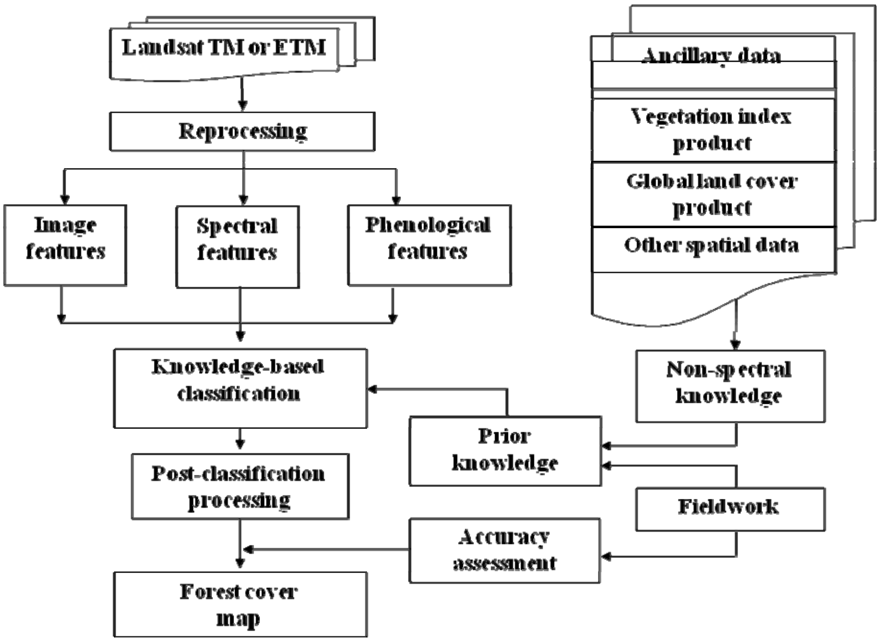


Figure 11. Flowchart of knowledge-based forest cover classification

2.3 Identifying driving forces of forest cover changes

For the identification of driving factors, we limited our analysis to the role of economic activity, population and elevation in determining land-cover change. The local case studies described above have already indicated a strong linkage between livelihood activities of the populace and forest cover. As policies are usually implemented at the national level, we are particularly interested in investigating whether insights at the local level are applicable at the national level as well.

3.0 Results & Discussion

3.1 Changes in forest cover between 1990s and 2000s

Figure 12 and Figure 13 are the land cover maps for 1990s and 2000s, respectively. Table 4 shows the aggregated statistics of changes in forest cover between 1990s and 2000s. Total area of these three countries under forest cover as estimated by RS-based analysis was 161.64 and 137.35 Million ha (Mha) in 1990s and 2000s, respectively, indicating a forest cover net loss of 15%. At the country level, the forest cover in Indonesia decreased from 120.96 Mha in 1990s to 100.21 Mha 2000s, representing the largest net loss of forest cover of -17.2% among the three countries. Malaysia and Thailand also showed a net negative change in forest areas during the period of 1990s-2000s.

Table 4. Change in forest cover area between 1990s and 2000s **Unit: 1000 ha**

Countries	1990s	2000s	Net change in forest areas	Percentage of net change
Indonesia	120957	100208	-20748	-17.2%
Malaysia	23605	21786	-1818	-7.7%
Thailand	17073	15355	-1718	-10.1%
Total	161635	137349	-24285	-15.0%

Our estimates are higher than the FAO's Global Forest Resources Assessment data (FAO, 2005) shown in Table 5. The main reason for difference is due to the spatial resolution of Landsat TM and per pixel classification approach. Landsat TM satellite images has a moderately high spatial resolution of 30m, but in many forested areas of the tropics the landscape is heterogeneous, and forest classes are highly intermixed with other vegetation types such as grasslands or scrublands at a pixel level, resulting in mixed forest cover classes. Spectral signatures also overlap with other categories and the pixel homogeneity is significantly lower. When allocating these mixed classes to a certain land cover category, it is difficult to some extent because the maps are forced to fit the real world into categories.

Table 5. Change in forest cover area between 1990 and 2000 by FAO Unit: 1000 ha

Countries	1990	2000	Net change in forest areas	Percentage of net change
Indonesia	116567	97852	-18715	-16.1%
Malaysia	22376	21591	-785	-3.5%
Thailand	15965	14814	-1151	-7.2%
Total	154908	134257	-20651	-13.3%

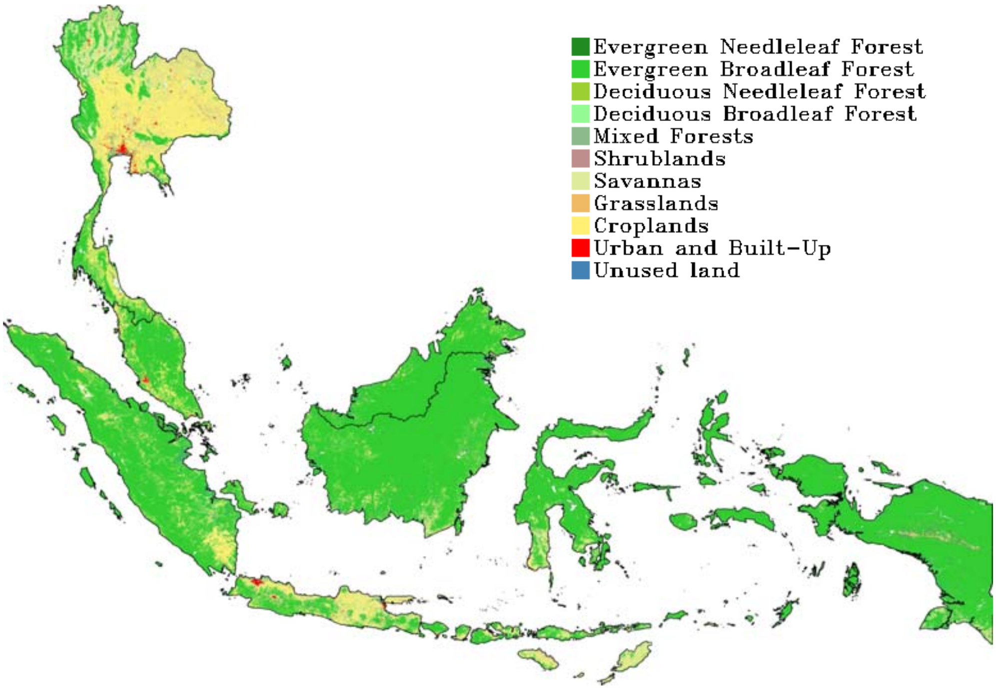


Figure 12. Land cover classification map in 1990s

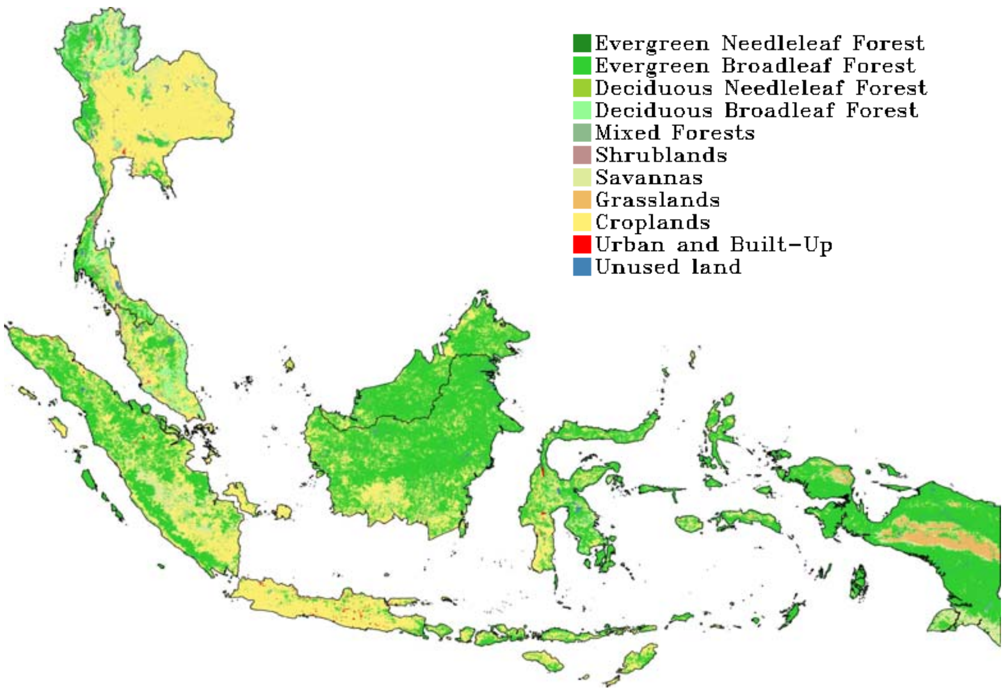


Figure 13. Land cover classification map in 2000s

3.2 Changes in forest cover locations between 1990s and 2000s

By overlaying Figures 12 and 13, it is possible to understand the changes in forest cover locations between 1990s and 2000s. Figure 14 shows the results of such overlay, whereas statistics of changes in forest cover locations are shown in Table 6.

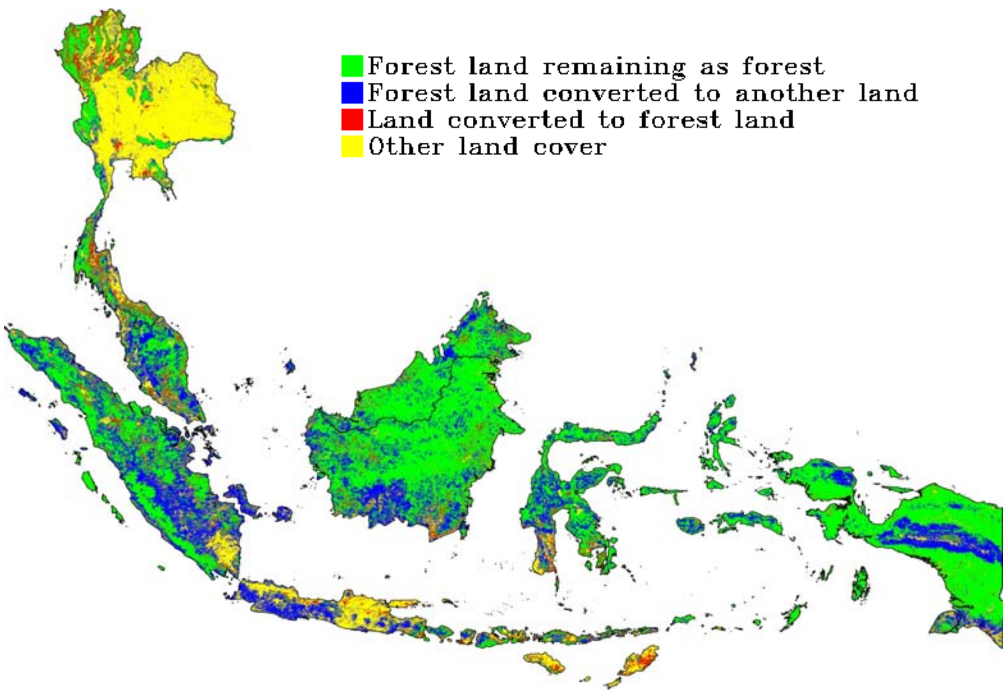


Figure 14. Changes in forest cover between 1990s and 2000s

Table 6. Change in forest cover locations between 1990 and 2000 **Unit: 1000 ha**

Countries	Forest land remaining as forest	Forest land converted to another land	Land converted to forest land	Net change in forest areas
Indonesia	94475	-26471	+5731	-20740
Malaysia	19438	-4161	+2352	-1809
Thailand	12029	-5035	+3322	-1713
Total	125942	-35667	+11405	-24262

It can be seen that for the three countries as a whole, there are about 35.67 Mha of forest lands converted other land covers, and about 11.41 Mha of other land converted to forest land during 1990s-2000s, resulting in a net loss of forest land by 24.26 Mha. Among of these, Indonesia has the largest forest land losses, accounting for 86% of the total loss. In addition, there are also about 5.73 Mha of forest gains by afforestation or reforestation, either by natural or by artificial regeneration (including plantations) in Indonesia, which is followed by 2.35 Mha and 3.32 Mha of forest cover increase in Malaysia and Thailand, respectively between 1990s and 2000s. The persistence of forest is highest for Indonesia (94.47 Mha), a phenomenon not unconnected with the large size of the Archipelago compared to the other 2 countries.

In Table 7, we show the loss of forest to other land covers between 1990s and 2000s. There is a similar trend among the countries: conversion of forest to croplands is the highest. In addition to this, there are about 11-17% of forest converted to woody savannas or savannas in Indonesia and Thailand. However, forest gains in these three countries differ from each other. Table 8 shows that forest cover increase in Indonesia and Thailand is mainly due to conversion of savanna and croplands to forest, with forest gains from savannah larger than from cropland. This is may be due to the fact that food production is high on the agenda of these 2 countries. Croplands reverting to forests in Malaysia can be explained by two factors. First, farmers took large areas of steeply sloping land on rubber plantations out of production, making the lands to revert to rubber-dominated secondary forests (Brookfield 1994). Second, steep slopes made oil palm cultivation economically unprofitable for many smallholders in Malaysia, so they allowed these lands to revert to forest. Last, rapid growth of urban labor markets leading to migration to cities help to explain the idling and spontaneous reforestation of agricultural lands on in Malaysia (Rudel et al., 2010)

Table 7. Conversion from forest to other land covers between 1990 and 2000 (Details of column 3 in Table 6)

	Indonesia	Malaysia	Thailand
To shrublands	0.1%	1.7%	9.2%
To savannas	17.2%	0.4%	11.5%
To grasslands	7.8%	0.7%	0.2%
To croplands	69.9%	93.3%	72.8%
To urban and built-up	0.3%	0.0%	0.1%
To unused lands	4.6%	3.8%	6.1%

Table 8. Conversion from other land covers to forest between 1990 and 2000 (Details of column 4 in Table 6)

	Indonesia	Malaysia	Thailand
From shrublands	2.2%	1.5%	0.4%
From savannas	51.2%	19.6%	65.2%
From grasslands	4.2%	4.9%	2.1%
From croplands	25.8%	64.6%	31.5%
From urban and built-up	0.2%	0.5%	0.1%
From unused lands	16.4%	8.9%	0.7%

3.3 Driving forces of forest cover change

In general, many variables can influence the forest cover changes, including biophysical factors (e.g. soil physicochemical properties and topography), demographic factors (e.g. population density), and socio-economic factors (e.g. income per capita, road accessibility and international timber trade). However, it is not possible to include all of these factors in our analysis, especially when studying forest cover changes over large areas. Besides, the major motivation is the linkage between economic activity and land-cover change. Thus, in order to understand the driving forces of forest cover change in the three countries, three main variables, namely, population, GDP and topography, were selected as the explanatory variables.

The gridded population and GDP data for the year 2000 was downloaded from International Institute for Applied Systems Analysis (IIASA) data center, Austria, and the DEM data (GTOPO30) with a horizontal grid spacing of 30 arc seconds was obtained from the Earth Resources Observation and Science (EROS) Center, USGS, USA. All these datasets were first re-projected and co-registered to a simple geographic (latitude/longitude, Plate Carrée) projection with a spatial resolution of 30 arc seconds, and then overlaid with the forest cover change map shown in Figure 14. All pixels of changes from forest to other land covers and all pixels of changes from other land covers to forest in one country were separately extracted with the corresponding population, GDP and topography values. These datasets were then input to SPSS software for regression analysis for each country. The resulting models are as follows.

(1) Conversion from forest to other land covers (FL)

Thailand: FL=860.60+0.036POP+0.004GTOPO-0.033GDP (R^2 = 0.76)

Malaysia: FL =898.34+0.041POP-0.003GTOPO-0.050GDP (R^2 = 0.61)

Indonesia: FL =770.78+0.143POP+0.002GTOPO-0.250GDP (R^2 = 0.74)

(2) Conversion from other lands covers to forest

Thailand: FG=421.21-0.004POP+0.160GTOPO+0.002GDP (R^2 = 0.77)

Malaysia: FG =201.56-0.006POP+0.036GTOPO+0.010GDP (R^2 = 0.72)

Indonesia: FG =208.50-0.001POP-0.001GTOPO+0.001GDP (R^2 = 0.65)

where FL is forest loss (conversion from forest to other land covers) in number of pixels, FG is forest gain (Conversion from other lands covers to forest) also in number of pixels, POP is population, GTOPO is elevation in meters, and GDP in US $. All variables are significant at the 0.05 level. The models above predict the quantity of forest loss or gain given the characteristics of a location described in terms of population, elevation and GDP.

It can be seen from above equations that forest cover loss in all three countries has a negative relation with population and a positive relation with GDP status, in particular for Indonesia. A higher population in the largely agrarian region results in an increase in demand for food, causing large proportion of forest cleared and used for crop cultivations to meet food needs. This explains further why 69.9%, 93.3% and 72.8% of forest loss in Indonesia, Malaysia and Thailand is due to the conversion from forest to croplands (Table 7). On the contrary, a lower GDP may stimulate more forest logging to expand the timber trades and output between South-east Asia and the rest of the world, resulting in higher deforestation. The regression results show that the topography may have negative or positive influences on the forest losses.

The model results for forest gain indicates a negative relationship with population, but a positive relationship with GDP for all the countries with the highest coefficient for GDP for Malaysia. This is not unconnected with the growth of urban markets that led to abandonment of agricultural land. Notice also that forests are more likely to be gained on higher elevations in Malaysia and in Thailand probably because they are more difficult to exploit than lower lying areas.

4.0 Conclusions

This study used Landsat TM and ETM+ imagery to map the forest cover for 1990s and 2000s and used post-classification analysis to detect land-cover change. The total area of these three countries under forest cover was 161.64 and 137.35 Mha in 1990s and 2000s, respectively, with a forest cover net loss of about 15.0%. Indonesia had the largest net loss of forest cover (-17.2%) among these countries. The study also found that for the three countries as a whole, there are about 35.67 Mha of forest lands converted to other land covers, whereas 11.41 Mha of other land converted to forest. Indonesia had 86% of the total forest loss. Forest losses in these three countries show a similar status and are mainly due to conversion from cropland. Forest gains in these three countries differ from each other – the increase in Indonesia and Thailand is mainly due to conversion from savanna to forest and from croplands, while that Malaysia is largely due to conversion of croplands to forest (64.6%). The analyses of driving factors suggest that the changes are primarily connected to economic activities in the region.

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Chapter 9

Modeling changes in carbon due to land-cover changes

Ademola K. Braimoh and Shubhechchha Thapa

Introduction

The major interest here is to model C storage as well as estimate changes in C as a result of the land-cover changes mapped in Chapter 8. Such C estimation is important from the point of view of mechanisms such as Reducing Emissions from Deforestation and Forest Degradation (REDD), a program designed to create a financial value for the carbon stored in forests by offering incentives for developing countries to reduce emissions from their forests and invest in low-carbon alternatives to sustainable development (http://www.un-redd.org). Secondly, C estimation is crucial as there is usually a spatial correspondence of carbon density and biodiversity and other ecosystem services (see Chapter 1).

The sequestered and lost carbon in the landscape between 1990s and 2000s was estimated using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) software (Nelson et al. 2009). The InVEST tool consists of a suite of models that use land cover maps for quantifying and mapping the levels and economic values of ecosystem services (e.g. carbon storage) provided by the landscape (Tallis et al. 2010). InVEST is largely data-driven with results presentable in both biophysical and monetary terms. To model C sequestration, InVEST requires estimates of four fundamental carbon pools: above ground biomass, below ground biomass, soil and dead organic matter. The model aggregates the C in each of the pools to arrive at the estimated C storage in each grid cell and across the entire landscape. Carbon pool estimates for the study area (Table 1) were established following guidance from the literature (Chen et al. 2009; Shanmughavel 2001; Tallis et al. 2010; IPCC 2006). Carbon sequestration/loss over time was computed by subtracting the estimated C storage in 1990s from that in 2000s. To estimate the monetary value of C sequestration or loss, we also computed the social value of carbon using the unit cost of $43 per ton of C (Tol 2005). The social cost of carbon is the marginal damage associated with the release of an additional metric ton of carbon into the atmosphere. It is also equivalent to the monetary benefit of an additional sequestered metric ton of C (Nelson et al. 2009). A discount rate of 7% was applied for the value of C in 2000 to reflect the decrease in monetary value over time.

Table 1: Carbon pools used for the analysis (Mg/ha)

LULC	Land cover	Above ground	Below ground	Soil	Organic matter
1	Evergreen Needleleaf Fore	90.00	60.00	95.00	29.00
2	Evergreen Broadleaf Fores	180.00	120.00	120.00	55.00
3	Deciduous Needleleaf Fore	80.00	55.00	80.00	35.00
4	Deciduous Broadleaf Fores	160.00	100.00	110.00	65.00
5	Mixed Forests	90.00	60.00	110.00	30.00
6	Shrublands	8.00	8.00	25.00	3.00
7	Savannas	100.00	20.00	75.00	25.00
8	Grasslands	6.00	6.00	20.00	2.00
9	Croplands	3.00	2.00	5.00	1.00
10	Urban and Built-Up	0.00	0.00	0.00	0.00
11	Unsed land	0.00	0.00	0.00	0.00

Results

The C stock ranged from 0 – 475 Mg C per ha for the three countries (Figures 1 – 3). The relatively high maximum value of 475 Mg C per ha reflects the fact that we took the 4 fundamental C pools into account, unlike other research that reports only the above ground biomass (e.g. Gibbs et al. 2007).

In the 1990s, the total terrestrial C in Thailand was the least (about 10 billion tons) whereas that of Indonesia was the highest (97 billion ton), a trend that largely reflects the relative size of the countries. By the 2000s, due to land-use change, Indonesia and Malaysia experienced about 25% decline in C whereas Thailand lost about 18% of its terrestrial C. This loss is equivalent to amounts ranging from $57 billion for Thailand to $780 billion loss for Indonesia.

	Total 1990s Million ton	Total 2000s Million ton	Net Change Million ton	Net Change Million $
Thailand	9932	8159	-1773	-57278
Malaysia	14352	10823	-3529	-114041
Indonesia	97662	73498	-24164	-780865

Figures 1 – 3 provide various insights vis-à-vis the current interests in C markets. They show that the damage due to emissions from deforestation on the landscape can be up to $15350 per hectare depending on the type of forest converted. In other words, if deforestation was to be halted and a reforestation program instituted, the monetary benefit of an additional sequestered metric ton of C could beup to $15350 per hectare. Note however that not all the sequestration estimates in the figures may be eligible for trading in a carbon offset market. The maps thus provide information about parts of the country where such a reforestation program is required and the benefits that will ensue. Clearly, the eastern part of Thailand is mostly affected by deforestation and C emissions, whereas pattern of C emission for Indonesia and Malaysia is more random. The maps can also be used to determine the amounts payable to providers of ecosystem services; for instance if farmers are required to convert their croplands to forest in a payment for ecosystem services project. Furthermore the maps help to identify areas of high C density for protection/conservation. Lastly, the maps may be combined with other information to determine the capacity of a location to provide multiple ecosystem services.

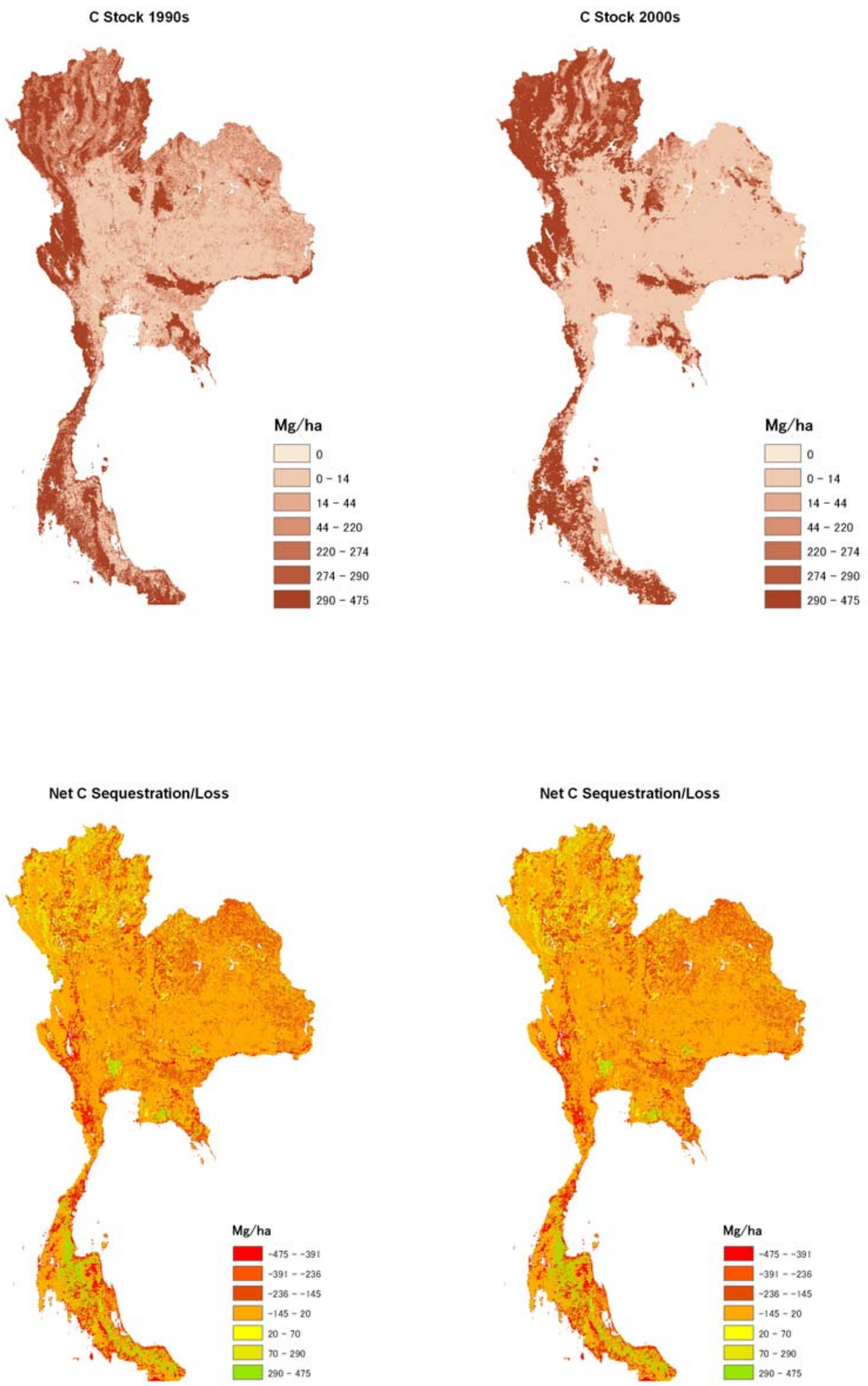

Fig 1: C stock and sequestration for Thailand

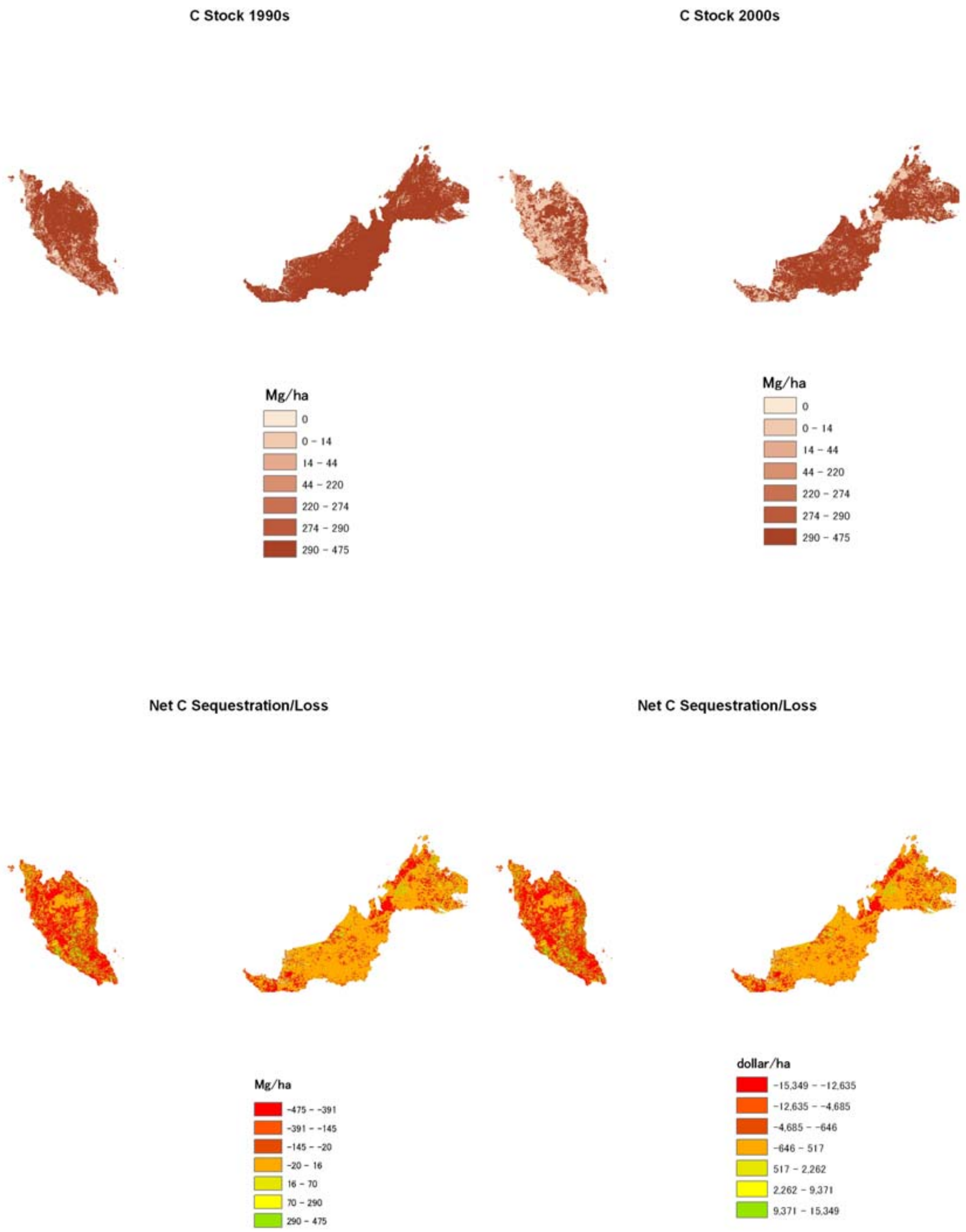

Fig 2: C stock and sequestration for Malaysia

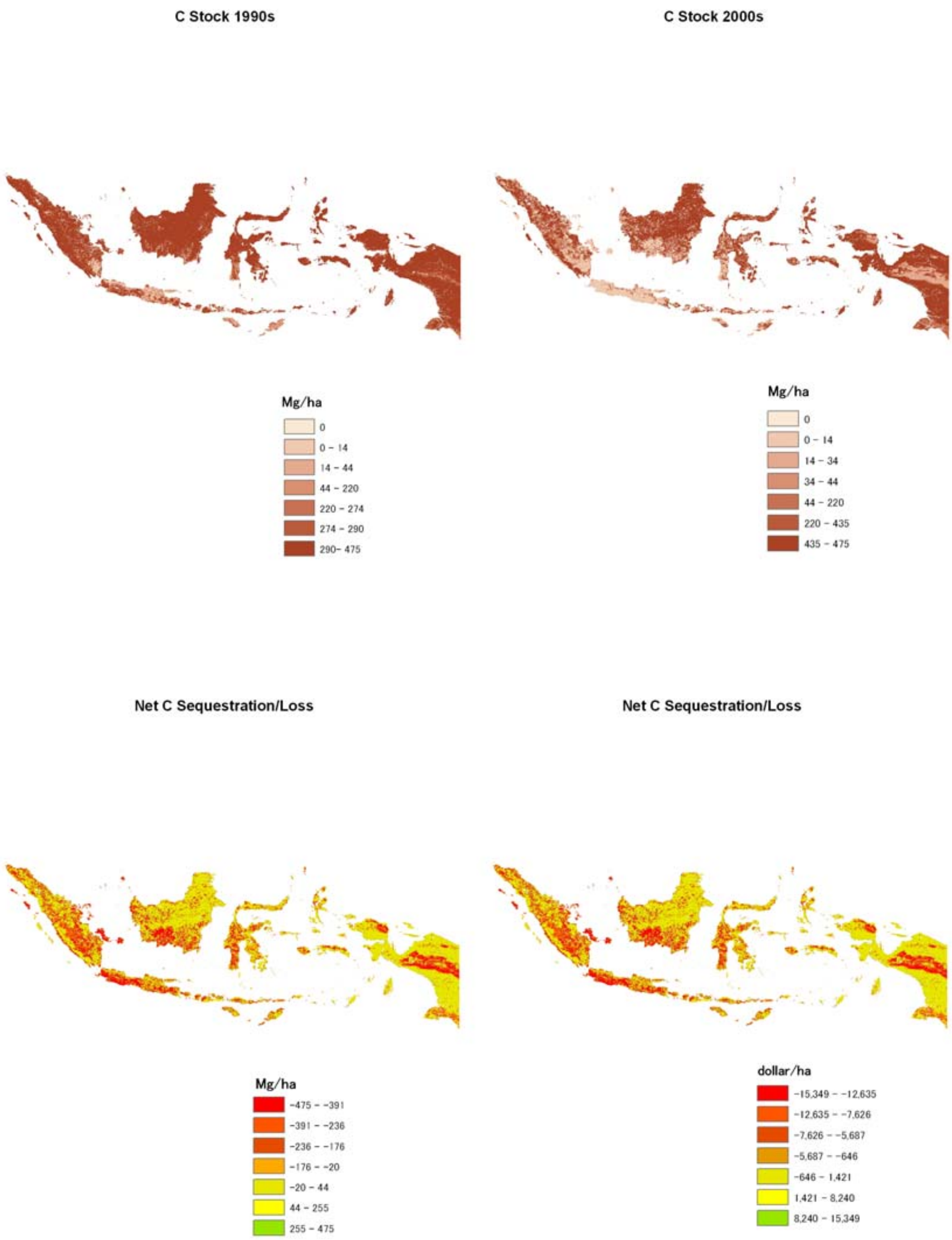

Fig 3: C stock and sequestration for Indonesia

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Appendix

Conferences/Symposia/Workshops

First working group meeting, Sapporo 1 – 2 July 2008
Workdhop on Vulnerability and Resilience of Land Systems in Asia, Beijing 15 – 17 June 2009
Synthesis Meeting, Yokohama, Yokohama 25 – 26 February 2010.

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- The Sustainability Governance Project, Hokkaido University supported the First Working Group Meeting, the Workshop on Vulnerability and Resilience of Land Systems in Asia and the Synthesis Meeting (ca $65,000) through the Special Coordination Funds for Promoting Science and Technology.
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- The International Fund for Agricultural Development and Echel Eau and Challenge Program on Water and Food support for Project PN50 (fellowship and to project director in Thailand) (ca. $16,000)

List of Young Scientists

- Mr. Songphonsak Rattinawilailak ('Mulu') carried out most of the field work for this study including interviews in local Karen language and their summary and translation into Thai. He has a Masters Degree in Non-formal Education and has been a Research Assistant at the Unit for Social and Environmental Research, Chiang Mai University for 3 years. He is a co-author of Chapter 4 and lead author of some of the publications that derive from it as well as a junior author of same others. Email: mulu1212@hotmail.com. *"This study helped me develop skills as a field researcher. I learnt how do design surveys and manage data collection and processing. I also learnt a lot about traditional and modern leaders and their roles in watershed management."*
- Mr Atsushi Shimahata was involved in the Indonesian case study as part of his Masters Research in Hokkaido University. He participated in Biomass estimation in the field and also carried out some remote sensing and GIS analysis (e-mail: atsushi.shimahata@ees.hokudai.ac.jp)
- Ms Shubhechchha Thapa, research assistant at the Global Land Project carried out C modeling and joined as co-author of Chapter 9 (e-mail: shubek@gmail.com)
- Ms Zhaohui Yang, a Masters Student carried out most of the interview at Supa Longling (e-mail: yangzhaohui1985@yahoo.cn). She also co-authored Chapter 6.