Landscape Agroforestry in Upper Tributary Watersheds of Northern Thailand

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Abstract

Landscapes of upper tributary watersheds are being transformed, and social, economic and ecological 'distance' between lowland and upland areas is disappearing. As lowland concern about natural resource sustainability grows, perceived impacts of changing upland agriculture on biodiversity, climate change and downstream watershed services have become a focus of debate and conflict. Evolving agroforestry concepts provide a framework for understanding landscapes that include agriculture and forests, and for assessing impact on livelihoods and the environment.

This paper summarizes recent assessments of impacts of various alternative land use practices currently found in the Mae Chaem watershed. Biophysical studies include impacts on plant biodiversity, carbon stocks, methane flux, stream flow and soil properties, while economic studies assess major crop production approaches and environmental concerns. These studies, conducted during 1997-2001 by researchers from ICRAF, the Royal Forest Department, Chiang Mai University and other partners working with ASB-Thailand, indicate that views of various land use practices as 'good' or 'bad' often break down on closer examination.

Research findings are then synthesized to examine trade-offs associated with the various approaches to land use, and assess alternative scenarios of approaches to agroforestry landscape management. Again, answers are not simple, and overall outcomes will depend on balance and configuration within types of agroforestry landscapes.

Given the increasing role of local governance institutions in managing both natural resources and growing conflict, the final section summarizes findings of some pilot studies exploring institutional dimensions of planning, managing and monitoring local landscapes that can help address central issues of growing land use conflict. Findings identify need for a monitoring and spatial information management system that can interface with and support localized natural resource and conflict management. ASB-Thailand is collaborating in development of a pilot system to provide prototype experience for policy formulation and larger development efforts.

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A. Land Use in Upper Tributary Watersheds: Debate, Tension & Conflict

Dominant societies in mainland Southeast Asia are centered on major river valleys and lowland areas where land has largely been cleared of forest and converted to agriculture. Agricultural production in lower zones of major river basins, including globally important 'rice bowl' production areas, has been the primary target and beneficiary of agricultural research and development. Lowland zones are also where centers of political power are located, and where rapid economic growth is focused, particularly in growing urban-industrial mega-cities.

Upper tributary watersheds of major river basins are located in mountain areas now collectively known as montane mainland Southeast Asia (MMSEA), a zone associated with:

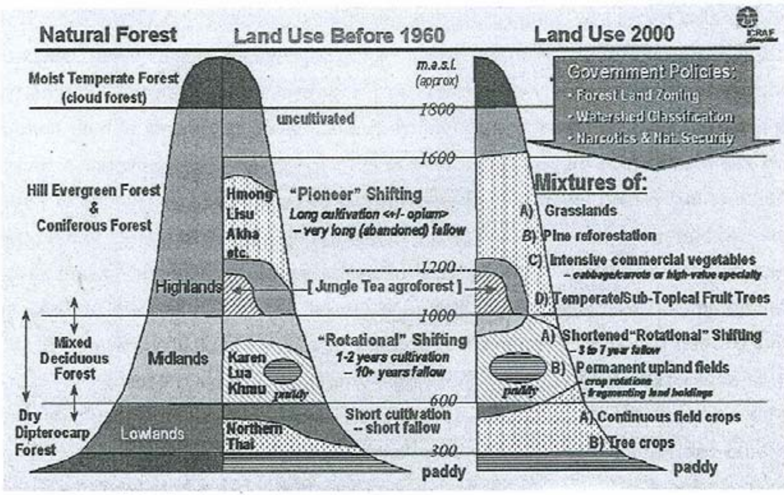
- Watershed headlands that include most remaining forest cover
- Diverse ethnic minority populations with poor access to services and markets
- Agricultural systems that often include shifting cultivation, and sometimes opium

Natural ecological gradients result in a series of natural forest types that correspond roughly to altitudinal zones. Prior to about 1960, these zones also corresponded with relatively distinct forms of land use practiced by ethnic groups associated with each zone.

During recent decades, various incentives and pressures have been driving land use change in upper tributary watersheds in Northern Thailand. In addition to social and economic forces that have brought sweeping change across larger Thai society, a range of government policies, programs and projects have been directed toward opium crop substitution, settling shifting agriculture, providing services and infrastructure, and protecting forest resources in these areas. As a result, landscapes of upper tributary watersheds are being transformed, and the social, economic and ecological 'distance' between lowland and upland areas is disappearing. Major components of this change are diagrammed in Figure 1.

As demand for water grows and diversifies in lowland society, competition for water increases. And, as a politically powerful middle class emerges in lowland urban-industrial centers, concern grows about longer-term sustainability of water supplies and environmental services. The tendency has been for lowland societies to look upstream for the source of their growing problems. Thus, upper tributary watersheds have become a focus of national and international environmental concern related to water, biodiversity and climate change.

An important component of this trend has been the emergence of intensive debate in the public policy arena about agricultural systems in mountain areas of upper tributary watersheds, and particularly those in Northern Thailand that are part of the greater Chao Phraya river system. Stated in their extreme, the two sides of this debate are:



source: ASB-Thailand

Figure 1. Changing land use patterns in north Thailand.

1. Pessimistic View: 'local mountain agricultural systems are bad'

This point of view is held to various degrees by conservation-oriented NGOs, as well as by many government agencies, biophysical scientists and others, with a particularly strong base in larger urban areas. A central element of this view is that 'proper' agriculture involves continuous cultivation of crops in fixed fields located on flat land. Thus, all types of shifting cultivation are considered as primitive, destructive, wasteful, and generally 'improper' forms of land use. These views have been reinforced by international interests, beginning in the 19th century with foresters focused on development of timber export industry, and more recently by environmentalists seeking to preserve ecosystems 'unspoiled' by human activity.

2. Optimistic View: 'local mountain agricultural systems are good'

This opposing point of view is held to various degrees by development-oriented NGOs and many social scientists, human rights activists, journalists and others. A central thesis of this view is that mountain communities have long been an integral part of these ecosystems, so that whatever practices they use are 'indigenous' and therefore 'good'. Lowland views are ethnocentric and self-serving. Any downstream problems are of their own making, and any negative upland trends are associated with misguided pressures to change mountain agricultural systems. Local communities should have full authority to decide how to manage mountain forests. These views are also backed by various international interest groups.

As debate has become more polarized, many have incorporated one of these perspectives into their worldview, often without any conscious effort. More extreme advocates of either view often refuse to listen to opposing views, appear unable to understand arguments of their opponents, and commonly seem convinced that opponents are only motivated by sinister ulterior motives.

Much of this debate assumes a choice must be made between agricultural or forestry forms of land use, so that many feel they must take one side or the other in response to the question 'can people and forest live together?'. While most effort appears to be directed toward victory of one view over the other, Their Majesties the King and Queen and other members of Thailand's Royal Family have been the most prominent advocates of a vision that incorporates a Middle Way approach in seeking ways to best meet both local and larger societal needs.

The science of agroforestry investigates the interface between agricultural and forestry forms of land use, and seeks to improve understanding of ways in which reasonable balances between both types of land use objectives can increase overall benefits to land use managers and broader society. In order to further explore and develop agroforestry approaches that can help address issues of growing tension and conflict related to land use in upper tributary watersheds, the International Centre for Research in Agroforestry (ICRAF) has joined with the Royal Forest Department (RFD) and Chiang Mai University (CMU) to conduct research in north Thailand in association with the global ASB Initiative.[4] An organizational umbrella for multi-institutional interdisciplinary research into the impacts of various forms of land use change on rural livelihoods and environmental services is provided by the ASB-Thailand consortium, which is chaired by the RFD.[5] Studies are conducted under a special RFD project (Figure 2), in close collaboration with RFD research and conservation offices, CMU and other universities, implementation projects in Mae Chaem, local governance bodies and other local actors; we also coordinate with Royal Project Foundation staff in sites under their responsibility.

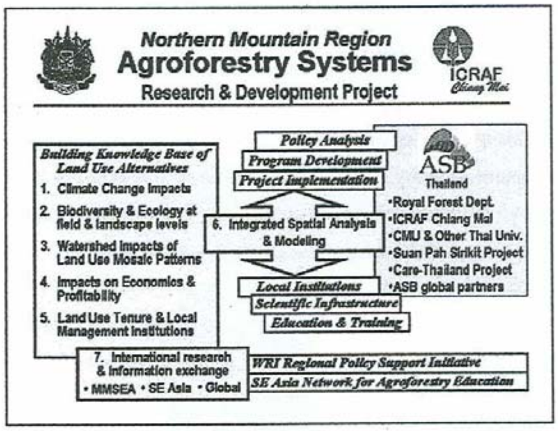


Figure 2. ASB-Thailand partnerships.

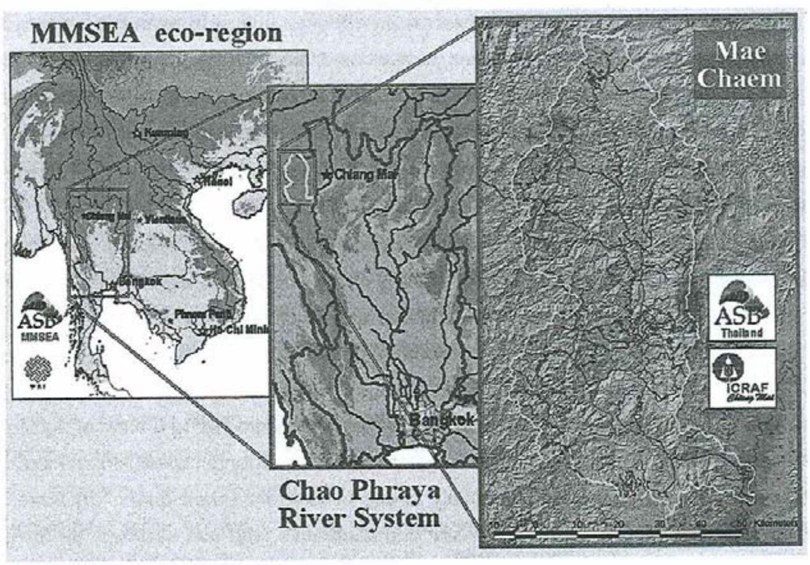


Figure 3. The Mae Chaem benchmark site.

The primary focus of detailed research studies has been within a benchmark research site that centers on the 4,000 sq km Mae Chaem watershed (Figure 3). This sub-basin is an upper tributary contributing about 40 percent of the water flowing into the upper Ping River, which itself is the largest tributary of the Chao Phraya River. As in many other upper tributary watersheds, while most all land in Mae Chaem is classified as protected watersheds or national parks, the 60,000 people living there (72 percent ethnic minorities) depend on these lands for their livelihoods. As a result of pressures and incentives during the last 20 years, including rural development and opium crop substitution projects, a spatially distributed pattern of land use change reflects various stages and pathways of transformation.

The following sections of this paper summarize findings of numerous research activities under the ASB-Thailand umbrella during 1997~2001, which have sought to provide science-based data and information that can help address policy-relevant issues related to debate, tension and conflict associated with land use change in upper tributary watersheds. We begin with articulation of an agroforestry framework for classifying mountain area land use systems, followed by preliminary assessments of major biophysical and economic impacts of major land use components, and associated environmental concerns. We then draw on these findings in examining biophysical and economic trade-offs among land use practices, as well as different agroforestry landscape scenarios. The final section presents work on institutional dimensions of managing local landscapes and land use conflicts, including on-going efforts to develop and test spatial information systems that can strengthen and support local capacities in these areas.

B. An Agroforestry Framework for Assessing Mountain Area Land Use

The concept of agroforestry has evolved rapidly during the last decade. A recent paper[6] discusses developments in the scope and content of the concept of agroforestry, and how it is affecting work by ICRAF and its partners at global and Southeast Asia regional levels, including work in Thailand and the montane mainland Southeast Asia (MMSEA) eco-region.

A central issue underlying much of the change in agroforestry approaches relates to a shift from viewing agroforestry as a set of stand-alone field-level technologies to a view of agroforestry as a phase in the development of productive agroecosystems and landscapes. Increased emphasis on ecology and agroecosystems is particularly strong in three important areas: (i) Assessment of complex ecological effects of both agroforestry and alternative land use systems; (ii) Integration of socio-economic and biophysical processes; (iii) Approaches for improving predictions at larger scales and across time.

Several elements of this conceptual evolution are particularly relevant for understanding current and potential roles for agroforestry in upper tributary watersheds of northern Thailand.

These concepts have been combined in a framework for classifying agroforestry systems in northern Thailand.[10] Table 1 indicates how this approach identifies field and landscape-level agroforestry systems centered on both sequential and simultaneous approaches. This generic classification helps organize and interpret investigations of agroforestry systems and their role in rural livelihoods and landscape management, as well as their comparison with alternative forms of agroecosystem management.

C. Assessing Impacts of Mountain Area Land Use Practices

Land use practices vary in their economic and environmental characteristics. Thus, ASB-Thailand research has sought to measure a range of impacts of agroforestry and alternative forms of land use. This section summarizes some of the major findings.

1. Biophysical impacts on the natural resource base

a. *Plant Biodiversity*

Whereas most biodiversity studies have focused primarily on species richness in natural forest ecosystems, ASB-Thailand has sought to assess vascular plant biodiversity across a range of land use types found in mosaic landscape patterns. Key studies have included:

- Rapid assessments of plant biodiversity using plant functional attribute (PFA) methods were conducted by a team led by Dr. Andy Gillison at 28 sites selected to represent a range of natural conditions and land use types[11];
- A study focused on forest biodiversity was conducted by Dr. Soontorn Khamyong and his staff from the CMU Department of Soil Science and Conservation, who combined PFA assessments with plant community analysis, including a forest condition index (FCI), at 36 sites on transects along altitudinal gradients on each side of the Mae Chaem valley; [12]
- An ethnobotany study of local use of biodiversity was conducted by Wanaree Charoensup, an M.Sc. student from the CMU Faculty of Science, in two midland villages (one ethnic Karen and one ethnic Lua) where shifting cultivation systems currently use a 5-year rotation cycle, and a second Karen village where agriculture is now conducted on fixed fields.[13]
- Some data on biodiversity in complex lowland Thai home gardens was gained from a study of 24 sites, led by Sittichai Ungphakorn of the Royal Forest Department[14].

Table 1. Types of Agroforestry

1. Sequential Systems *(maximum growth rates at different times)*		
1.a. Field-Based Systems (unit = single field)	***Source***	***Status***
Pioneer Shifting Cultivation [mature forest→repeated cropping→'abandon']	indigenous	very rare
Relay & Transitional Intercrops [(young trees + crops)→forest or orchard]	old (taungya)	establish plantations & orchards
Rotational Systems		
-- **Annual - Perennial Crop Rotations** [annual → short perennial crop]	unknown	unknown
1.b. Landscape-Based Systems (unit = many fields + common land)	***Source***	***Status***
Forest Fallow Swidden	indigenous	degrading
[1-2 crops → (long) natural fallow] + protected areas		
Composite Forest Fallow Swidden	indigenous	degrading
permanent paddy + [1-2 crops → (long) natural fallow] + protected areas		
Intensified Rotational Systems		
-- ***Improved Fallow Management***	local	little study
[1-2 crops → short improved fallow] + protected areas (+/- paddy)		
-- ***Annual - Perennial Crop Rotations***	unknown	unknown
[annual → short perennial crop] + protected areas (+/- paddy)		
2. Simultaneous Systems *(grow at same time → competition / trade-off effects)*		
2.a. Field-Based Systems (unit = single field)	***Source***	***Status***
Regular Pattern Systems		
-- **Row Pattern:** e.g. orchards, alley cropping, countour hedgerows	induced	promoted
-- **Linear Pattern:** e.g. boundaries, live fences, windbreaks	local	Some promotion
Mixed / Irregular Pattern Systems		
-- **Home Gardens:** mixed species, age; multi-storey	indigenous	promoted
-- **Complex Agroforests:** very diverse, forest-like; e.g. miang tea	local	little study
-- **Silvo-Pastoral Systems:** trees, palatable shrubs, pasture	little study	little study
2. b. Landscape-Based Systems (unit = many fields + common land)	***Source***	***Status***
Community Mosaic Systems: multi-level management [household + community + local govt]		
-- ***Watershed Mosaic:*** sited / managed to preserve watershed functions	induced	emerging promoted
permanent fields (annual + perennial) + perm. watershed forest		
-- ***Protected Forest Mosaic:*** sited / managed to preserve forest services	local & induced	emerging
permanent fields (annual + perennial) + protected forest		

Table 2. Estimates of plant biodiversity of various land uses in Mae Chaem

	A Gillison et.al. 28 sites		S Khamyong et.al. East Transect		S Khamyong et.al. West Transect		Wanaree 3 Villages		Sittichai 24 sites
	Species	PFC	Species	FCI	Species	FCI	Species	%Useable	Species
Natural Forest									
Hill Evergreen	48-69	416-703	62	Interm	65	Good	44-53	60-98%	
Hill Pine	39-54		37-64	Interm	39	Good			
Mixed Deciduous	40*	490*	76	Good	86	Good			
Dry Deciduous	31-50	287-436	58	Interm	38-45	Poor	27	78%	
Sequential Agroforestry									
-10yr fallow	63	513							
- 5yr fallow	64	498					35-42	86-88%	
-3yr fallow	43	445					40-61	75%	
-1yr fallow	40	292					30-41	71-87%	
Simultaneous Agroforestry									
Home Garden									21-76
Fruit trees + vegetables									
Coffee/shade AF	33	250							
Annual Crops									
Paddy Rice Field	30	192					38	95%	
Upland Rice field	33	249					43-47	91-93%	
Maize									
Intensive Vegetables	7	58							
Total Landscape			*138*		*180*		*126-137*	*67-85%*	

Findings from these preliminary studies, which are summarized in Table 2, indicate that:

- Although sample size was still too small to characterize the full range of land use variation found in Mae Chaem, findings do indicate increasing plant functional complexity (PFC) along a series of fallows of increasing age, towards complex forests. These are also distinguished along a seasonality/precipitation gradient separating evergreen from deciduous vegetation.
- Permanent agricultural fields have lower levels of plant functional complexity and species richness. However, rotational forest fallows with 5 to 10 years of growth in hill evergreen zones may approach levels comparable to natural forest, although structural characteristics such as canopy height and basal area are significantly less than more mature forest.
- While confirming the extensive knowledge of these ethnic communities regarding use of natural plant species, findings suggest that impacts of decreased forest fallows on local forest product availability may not be as severe as some have claimed. Further analyses are needed, however, to assess the nature of plants and their products that may be more abundant in fallow fields, and the role of these products in local livelihoods.

b. Climate change

Contributions of changing land use patterns to global climate change are indicated by the manner in which they affect carbon sinks and GHG emissions. In order to help improve assessments associated with the types of mosaic land use patterns found in upper tributary watersheds of northern Thailand, ASB-Thailand studies have made preliminary assessments of both carbon stocks and methane dynamics in various forest and other types of land use.

(1) Carbon Stocks

A study of carbon stock levels of various components of land use mosaic patterns in the Mae Chaem watershed was organized by Dr. Attachai Jintrawet, and conducted by researchers of the CMU Faculty of Agriculture[15], based on assessments using standard ASB methods at thirty-five sites. Basic findings for 4 categories of land use are presented in table 3.

Table 3. Estimated carbon storage of various land use types in Mae Chaem

	Above-Ground carbon — tons hectare^{-1} —					Soil 0-30 cm	total Carbon	above surface Share % total	Soil BD Gm cm^{-3}
	green	litter	tree	dead	Sub-tot				
Natural Forest									
Hill E-G (max)	1.7	6.1	190.9	54.0	252.7	122.4	375.1	67	0.97
Hill E-G (ave)	1.5	3.6	88.2	25.2	118.4	93.7	212.1	56	0.93
Hill Pine	1.3	2.9	69.3	5.3	78.7	73.0	151.7	52	1.08
Dry Deciduous	1.3	1.3	49.0	8.3	59.9	59.9	119.7	50	1.27
Sequential Agroforestry (rotational forest fallow)									
-10yr cycle (time ave)	3.3	3.8	31.0	12.8	51.0	107.4	158.4	32	1.18
-6yr cycle (time ave)	2.7	2.6	10.8	-	16.1	60.1	76.2	21	1.02
-3yr cycle (time ave)	1.9	1.1	-	-	3.0	47.8	50.7	6	1.22
Simultaneous Agroforestry									
Fruit trees + vegetables	1.2	1.0	2.4	-	4.6	152.9	157.5	3	1.19
Coffee/shade AF	0.6	1.7	25.2	23.8	51.4	127.4	178.7	29	1.12
Annual Crops									
Upland Rice field	1.7	0.6	-	-	2.3	22.4	24.7	9	1.33
Maize	6.4	0.3	-	-	6.7	92.0	98.7	7	1.40
Veg	0.2	0.1	-	-	0.3	82.1	82.5	0	1.43

Major implications of these finding include:

- Maximum carbon storage is found in hill evergreen forest, and especially in relatively vigorous undisturbed stands. Pine and dry deciduous forest appear to store substantially less total carbon, but retain similar shares between above and below-ground storage.
- Both 10-year rotational forest fallow systems and coffee under forest shade have time-averaged total carbon stocks somewhat less than average natural forest in Mae Chaem, with a modest decrease in the above-ground share. Systems that maintain some large trees during cropping may have fallows as short as 6 years without changing these properties.
- As forest fallow rotations are shortened to a 6-year cycle (with full clearing), time-averaged total carbon drops to about half of pine and dry deciduous forest, with relatively more carbon found below ground. This raises the question whether the longer-term trend of these systems would be toward a decrease in below-ground carbon.
- Once forest fallow rotations are shortened to a 3-year cycle, time-averaged carbon stocks appear more similar to permanent agricultural lands, where more than 90 percent of carbon is stored below ground. Relatively higher below-ground carbon may be associated with recently cleared fields, and\or high applications of manure and mulch in crops.
- Soil bulk density is related to carbon stored in the litter layer: (i) highest average levels of carbon in litter and lowest average soil bulk density were in hill evergreen forest, pine forest, and both 10 and 6-year forest fallow systems – extreme values were in fertile hill evergreen forest. (ii) intermediate levels of litter carbon and soil bulk density were found in dry deciduous forest, 3-year forest fallow systems, fruit tree/vegetable agroforestry, and coffee under forest shade. (iii) lowest levels of litter carbon and highest soil bulk densities were found in permanent fields producing upland rice, maize and vegetables.
- Since low soil bulk density is associated with higher rates of water infiltration and methane uptake (see below), findings indicate 6 to 10 year forest fallow systems would have relatively little impact on water infiltration and methane uptake compared to natural forest conditions. Very short cycle (3-year) fallow systems and fixed field agroforestry would have some impact, but much less than fields continuously planted to annual crops.

At the broader agroforestry landscape level, shorter forest fallow cycles in the midland zone are reducing carbon stock levels from those found in traditional long-fallow systems. In some project areas, however, various forest fallow and degraded forest plots are being returned to permanent forest. This could result in a net increase of carbon stock in the locally-managed landscape, especially if these parcels can return to mature fertile hill evergreen forest.

(2) Methane Dynamics

Study of methane dynamics associated with components of land use mosaic patterns in the Mae Chaem watershed were conducted by Chitnucha Buddhaboon and presented in a M.Sc. thesis[16] under the CMU Agricultural Systems Programme. Table 4 presents part of the findings based on replicated monthly measurements at 12 land use sites, and updated land use area estimates that became available more recently.

Some of the preliminary conclusions from this study include:

- Rates of methane absorption by upland land uses are more closely associated with soil bulk density than with vegetation type, with uptake rates ranging from 1.4 gm CH_4 ha^{-1} day^{-1} on more compacted soil (1.4 gm cm^{-3}), to 5.2 gm CH_4 ha^{-1} day^{-1} on less compacted soils (0.8 gm cm^{-3}) under forest fallows accumulating litter on gentle slopes with fire control. Thus, methane uptake is facilitated by any land use that maintains low soil bulk density.

Table 4. Preliminary estimates of the net methane flux in the Mae Chaem watershed

		Estimated Area hectares	% area	Absorption Rate gm ha^{-1} day^{-1}	Duration Days	Annual Absorption tons $year^{-1}$
	Hill evergreen	108,605	32.5	2.09	365	82.8
Natural Forest	Hill pine	38,313	11.4	1.61	365	22.5
	Deciduous	154,834	46.3	2.36	365	133.4
Forest fallow fields		11,428	3.4	5.17	365	21.6
Upland fields	fixed field/cabb	6,040	1.8	2.40	365	5.3
	non-cabbage 'swidden'	7,996	2.4	2.40	365	7.0
Paddy Rice	flooded	5,818	1.7	(689.20)	195	(781.9)
	non-flooded	5,818		1.44	170	1.4
Other		1,597	0.5	n.a.	n.a.	-
Total Watershed:		334,631	100.0			(507.9)

Source: Adapted from Chitnucha Buddhaboon (2000) with area estimates from DLD/CMU-MCC

- Rates of methane absorption by higher altitude forest appear lower than expected from associated soil bulk densities, which is probably due to lower temperatures at these sites.
- Rates of methane emission from flooded paddy fields were many times greater than methane uptake rates at any site. While surface soil bulk density affects methane absorption rates, it is the area and duration of paddy flooding that most strongly influences net methane flux at

broader landscape levels. Although paddy covers less than 2 percent of the Mae Chaem watershed, only 35 percent of methane emissions associated with rainy season flooding of rice paddies are taken up by the remaining 98 percent of the landscape.

Since methane emissions stop quickly after paddy returns to non-flooded conditions, one way to reduce emissions might involve paddy rice production methods using multiple short periods of flooding, as under study in China, IRRI and elsewhere. If such practices could reduce the annual period of flooding by 50 percent, without reducing rice yields, their use in Mae Chaem paddy lands could reduce net methane emissions of the watershed by 77 percent.

c. Watershed functions: impact of land use on stream flow.

A preliminary study of small watersheds with different mosaic patterns of land use was conducted by Warin Jirasuktaveekul and the RFD Watershed Research Group, with Dr. Nippon Tongtham of the Kasetsart University Faculty of Forestry as an advisor. [17] Five small sub-catchments (mean area 0.1 km^2) in Mae Chaem were selected to represent some major types of land use patterns: (a) Highland pine plantation and relatively young secondary hill evergreen forest; (b) Highland mosaic dominated by intensive vegetable production; (c) Highland short forest fallow shifting cultivation with cattle grazing; (d) Highland rotational agriculture including upland rice, cabbage and native grass; (e) Midland dry dipterocarp forest. Each sub-catchment was instrumented with: 1) a weir and water level recorder to measure stream flow discharge at the outlet, 2) data loggers recording rainfall, temperature and relative humidity, and 3) gypsum blocks to measure soil moisture. In order to compare relatively mature hill evergreen forest, comparable data were obtained from an RFD monitoring site at Doi Pui National Park.

Monthly rainfall and stream flow data for each of the six sites are presented in Figure 4. While first-year data cannot be conclusive, relative patterns among sites indicate that:

- Data of the first 2 months reflect very early heavy rains during a La Nina event, with high runoff and stream discharge at all sites with agricultural fields. After this unusual period, more 'normal' patterns appeared during subsequent periods.
- **Mature hill evergreen forest** clearly demonstrates its capacity to buffer fluctuating rainfall, smooth stream flow discharge, and provide relatively higher levels of dry season stream discharge. The dry season level is somewhat exaggerated by rains during November and December at that site, as seen in the upper bar chart, but the overall pattern is well known.
- The site with a mosaic dominated by **intensive vegetable production**, had much greater month-to-month fluctuation in stream discharge, and much lower dry season discharge level.
- The shape of the stream discharge curve for the **short forest fallow** mosaic is quite similar to the mature hill evergreen forest curve, but at a somewhat lower level. This may indicate a bit

less buffering, but there was also more late season rainfall at the hill evergreen site. A longer-cycle forest fallow would likely resemble hill evergreen forest even more closely.

- The **upland crop rotation** site appears to be intermediate between the short forest fallow mosaic and the intensive vegetable production mosaic.
- The **pine plantation – young secondary hill evergreen forest** site recorded much lower stream flow discharge levels than most sites, and stream discharge stopped during January. This may be due to somewhat lower total rainfall, as well as high evapotranspiration rates associated both with pine and with rapidly growing young secondary hill evergreen forest.
- The **dry dipterocarp forest** site recorded very low levels of stream discharge for only 3-4 months. This is likely due to a combination of soil factors and high rainy season rates of evapotranspiration from the large leaves of many trees in this type of forest. RFD staff are seeking data on dry dipterocarp forest at other sites in the country for comparison.

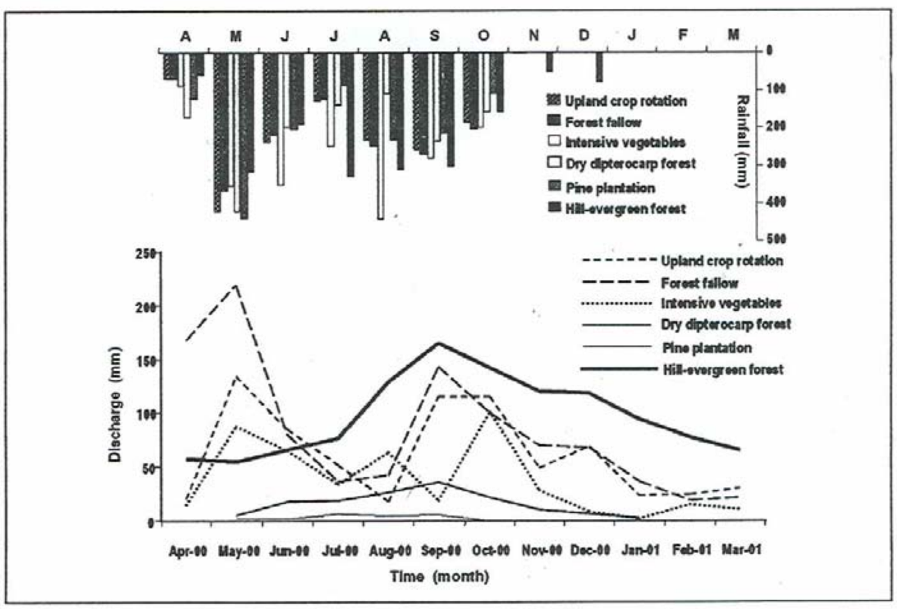


Figure 4. Rainfall & stream discharge, 2000~01.

Although data from a single year are not enough for scientific conclusions, relative patterns together with existing literature allow some preliminary inferences about impacts on:

- ***Fluctuation in stream discharge***. Findings indicate a progression of change in stream discharge, from a smoothly buffered pattern in mature hill evergreen forest, through increasing levels of intra-season variability as agricultural activities intensify and become more dominant. There appears to be a direct relationship between the degree of buffering and the relative level of dry season stream discharge.
- ***Total quantities of stream discharge***. Variation in total stream discharge appears linked with high rates of water loss through evapotranspiration, with highest rates – and lowest total discharge – in dry dipterocarp forest during the growing season, followed by the intensive vegetable mosaic (with sprinkler irrigation), and the pine plantation with young hill evergreen forest. Low total discharge is also associated with early seasonal cessation of stream flow.

d. Soil properties

Mountain communities are under strong pressure to reduce the cycle length of their forest fallow shifting cultivation systems. In order to investigate implications of shortened forest fallow cycles on agronomic sustainability of these systems, an intensive study of a Karen village using a 6-year rotation cycle but otherwise traditional practices was conducted by Prasit Wangpakapattanawong of the CMU Faculty of Science. An initial hypothesis was that a forest fallow system operating under these conditions should be under stress, and may not be sustainable over the longer term. Major findings are presented in his doctoral dissertation.[18]

Various researchers have suggested that forest fallows can assist with one or more of six major ecological functions related to sustainability. While this research focused primarily on the first function, some evidence was also obtained regarding others. Major findings include:

(1) Replenishing soil nutrients. Findings indicate nutrient stress under shortened fallows may not be leading to system collapse. This 5-year fallow appears sufficient to maintain major soil fertility factors, resulting in fairly low (one ton ha^{-1}) but sustainable upland rice yields with no fertilizer or chemical inputs. During the 5 year fallow there is an increase in soil organic matter and total N from litterfall of fallow species, along with a decline in pH, available P, and extractable K, Ca and Mg due to uptake by fallow vegetation and decline in effects of burning. Fertilizer trials showed N was the most limiting nutrient in upland rice productivity. Villagers believed 3 years would be an absolute minimum fallow period, which would likely be associated with increased weed competition and reduced ash from burning.

(2) Maintaining soil structure. Similarly, soil structure appears to be reasonably well maintained under this six-year cycle, with surface soil bulk density in forest fallow fields (about 1.0 gm cm^{-3})

comparing very favorably with those in nearby secondary forest. These findings agree with those from carbon stock assessments, which indicate that bulk density values under forest fallows of 5 or more years of age are comparable to most forest sites, and considerably better than those under dry deciduous forest or fixed agricultural fields.

(3) **Minimizing soil erosion.** Inspection of shifting cultivation fields indicated only slight to moderate erosion. A relatively low potential of soil erosion in forest fallow fields is inferred by soil bulk densities comparable to nearby forest, and by the short period of bare soil exposure during a season with low probability of heavy rainfall.

(4) **Providing useful plants.** Farmers cited many plant species found in fallow fields and nearby forest as useful for food, medicines or other purposes. Data from an ethnobotany study conducted in this village (see biodiversity section) confirm these findings with 61 of 85 total identified useable species found in fallow fields. However, less than 20 useable species were found only in fallow fields; others were also found in forest or currently cropped fields.

(5) **Controlling weeds.** New fallows at this site are initially dominated by *chromolaena odorata*, which is usually shaded out by tree species by the end of the second year. *Chromolaena* is seen as desirable due to its ability to grow fast, shade out grasses and more noxious weeds, produce high biomass (7.1 tons ha^{-1} in the 1st year) and decay rapidly. Researchers in some areas of Southeast Asia consider this a species for 'improved' fallow management. Although dominance of *chromolaena* appears to have helped reduce problems with grass weed species that are common in many areas of Mae Chaem, villagers increased weeding frequency from two to three times per year after their fallow cycle shortened to six years.

(6) **Controlling crop pests and disease.** Although study of these complex issues was not a research objective, an experimental second-year planting of rice was attacked by soil pathogens, resulting in root and lower stem damage, much lower total biomass, and almost no grain. This provides minor support for the role of fallows as an insect/disease break, as suggested by researchers elsewhere. It may also relate to observations where upland rice is cultivated on fixed agricultural fields, that even with chemical inputs a minimum crop rotation every third year to a crop like soybeans is necessary to prevent yield decline.

2. Economic Performance and Environmental Concerns

ASB-Thailand's core economic and financial research used modifications of the policy analysis matrix (PAM) approach.[19] Profitability of major crops was studied for a range of conditions found in the Mae Chaem watershed, using various combinations of survey and rapid assessment methods.[20] This section uses standardized estimates of farmer profitability[21], as well as profitability and returns to land using international prices without current distortions resulting from policies and market imperfections[22]. Environmental concerns were identified by discussions with stakeholders at various levels, biophysical research, and secondary sources.

a. *Rice Production*

Despite changing land use, rice remains the most prominent component of agriculture in Mae Chaem. Although rice is the mainstay of diets of all ethnic groups, the watershed has long experienced an overall rice production deficit, largely attributed to the limited area available for paddy establishment in mountainous terrain, and the relatively low productivity of upland rice.[23]

(1) Paddy Rice

Since paddy is clearly the rice production approach with highest productivity, in terms of both yield per unit area and returns to labor, it is not surprising that most rice producers use paddies to the extent that their natural, human and financial resources allow. As Table 5 indicates, profitability is generally somewhat higher than local wage rates. Higher profitability in a subsidized 2nd crop and some small paddy areas acquired by Hmong, may merit further study.

Analysis using international prices indicates that government policy encourages rice production, through both fertilizer subsidies and rice price supports. In contrast to some more profitable crops discussed below, if farm gate prices for paddy were closer to international market prices, profitability of paddy production would decrease rather than increase.

In terms of environmental concerns, paddy production usually uses chemical fertilizer and often herbicide; pesticide use is variable. Since much rainy season stream flow is diverted to flow through paddy lands, particularly in Karen and lowland Thai traditional irrigation systems, varying amounts of water pollution can occur below outlets where water flow returns to the stream. This factor, however, is not yet a major issue in upstream-downstream debate.

Table 5. Paddy rice production

		Location		Inputs & Technology							Product	Farmer	Internat Prices	
		Vill	Eth	Nutritent		Weeds		Pests		Labor	Yield	Profit	Farmer	Land
Crop	Year	Site	Grp	Ma	Fer	Sa	Her	Ins	Fun	days rai^{-1}	kg rai^{-1}	Bt day^{-1}	Bt day^{-1}	Bt rai^{-1}
Paddy Rice Production														
Main	1997	1.1	Ka		X		X			31	512	58	41	17
Main	1997	1.2	Ka		X	X	X			36	544	52	49	325
Main	1997	1.3	Ka		X					31	496	62	64	739
Main	1997	2.1	Ka	X	X					17	400	75	69	493
Main	1997	3.1	Ka							34	576	68	59	638
Main(trad)	1998	4.2	Th		X		X			37	576	72	40	11
Main (trad)	1998	4.3	Th		X		X	X		38	608	77	32	(325)
Main (HYV)	1998	4.1a	Th		X		X	X	X	37	576	49	67	1,008
Main (HYV)	1998	4.1b	Th	X	X		X	X	X	26	592	79	45	134
Main (HYV)	1998	4.2	Th		X		X			64	640	34	17	(1,490)
Main	1998	3.2a	Hm		X		X			12	752	239	181	1,736
Main	1998	3.2b	Hm		X					29	800	125	84	1,288
2nd Crop (HYV)	1998	4.2	Th		X		X			13	704	356	75	448

KEY: Th=Northern Thai, Ka=Karen, Hm=Hmong, Ma=manure, Fer=fertilizer, Sa=salt, Her=herbicide, Ins=insecticide, Fun=fungicide

In terms of soil degradation, paddies are excellent traps ('filters') for sediment from upstream, which even adds soil nutrients to paddies, at least up to the point that excessive or poor quality sediment begins harming the paddy environment. Water use is another issue, since significant amounts of water are lost through evapotranspiration during paddy rice production. Thus, water-scarce downstream communities are increasingly critical of increased paddy production in upstream areas. And, to the extent that climate change is perceived as an issue, methane emission rates from flooded paddy are such that zero net emissions would mean that under current practices one hectare of flooded paddy would need to be balanced by more than 160 hectares of the mix of upland landscape of the types currently found in Mae Chaem.

(2) Upland Rice

Given the limited sites for paddy in hilly midland areas, Karen and Lua communities also use traditional rotational forest fallow systems to produce subsistence upland rice and other products obtained from fallow fields and forests in their mosaic landscapes. Although evidence indicates forest fallow rotation cycles were traditionally about 10 years or more, pressures on land use have reduced rotation cycles to six years or less in most areas of the Mae Chaem watershed. Many government officials are urging further reductions, and fixed fields with crop rotations or short fallows are now found in many areas. Hmong communities also produce upland rice, usually in crop rotations or very short fallows with relatively high chemical inputs.

As the data in Table 6 indicate, relatively high upland rice yields are usually associated with either: a) rotational forest fallow cycles that approach 10 years in length; or b) crop rotations and relatively high levels of chemical and/or labor inputs used to assist with nutrient replenishment, weed suppression and pest management. Net profitability is higher under long forest fallow rotations, which require no chemical inputs. The 'high tech' Hmong approach is an exception, but this small area needs further investigation to understand its high profitability. Profitability at international prices shows mild effects of overall rice and fertilizer policies.

Table 6. Upland rice production

		Location		Inputs & Technology							Product	Farmer	Internat Prices	
		Vill	Eth	Nutritent		Weeds		Pests		Labor	Yield	Profit	Farmer	Land
Crop	Year	Site	Grp	Ma	Fer	Sa	Her	Ins	Fun	days rai^{-1}	kg rai^{-1}	Bt day^{-1}	Bt day^{-1}	Bt rai^{-1}
Upland Rice Production														
For fallow-8-10yr	1998	3.1	Ka							46	512	50	43	129
6-year 'priv' fallow	1997	2.1	Ka							13	208	53	51	151
Rot fields-2-3 yrs	1997	1.2	Ka	X		X	X			56	416	26	25	(829)
Fixed field	1997	1.1	Ka	X			X			28	320	46	34	(174)
	1997	1.2	Ka	X			X		X	70	544	24	23	(1,159)
	1997	1.3	Ka	X						44	304	30	30	(437)
Fixed field (trad)	1998	4.2	Th	X			X		X	41	128	(26)	(31)	(2,890)
		1998	4.3	Th	X					X	15	96	3	(32)
(1,081)														
Fixed field (HYV)	1998	4.2	Th	X			X			16	96	(11)	(15)	(874)
	1998	4.3	Th	X			X			25	96	(7)	(14)	(1,350)
Fixed field	1998	3.2a	Hm	X			X			27	560	126	44	112
	1998	3.2b	Hm	X			X			18	448	158	90	874

KEY: Th=Northern Thai, Ka=Karen, Hm=Hmong, Ma=manure, Fer=fertilizer, Sa=salt, Her=herbicide, Ins=insecticide, Fun=fungicide

Lowland Thai and international interests have long held strong positions against all forms of shifting cultivation, which are seen as 'destroying' natural forests. Indeed, most commercial timber and substantial amounts of carbon stocks are lost. In terms of watershed functions, however, longer-cycle (5-10 year) rotational forest fallow rice production appears to have relatively few negative watershed impacts. As fallows shorten, and at least when they drop to 3-4 years or upland rice production is transformed to a fixed field setting, various mixes of fertilizer, herbicide and pesticide applications appear to become inevitable, and some types of fields may become more susceptible to soil erosion and reduced water infiltration.

b. *Field Crop Production*

Major field crops produced in the Mae Chaem area include soybean and maize, which are usually sold through lowland markets for agro-industrial use. Profitability of these crops is roughly intermediate between paddy and upland rice, and they are an important source of cash in areas where chemical inputs are needed for subsistence rice production. Since the economic crisis and currency devaluation, crop prices have increased very little, but chemical input costs have risen rapidly. Thus, soybean profitability has dropped, and farmers are shifting to maize, where returns appear better due to new cultivars and contract farming with agro-industry.

Table 7. Field crop production

		Location		Inputs & Technology							Product	Farmer	Internat Prices	
		Vill	Eth	Nutritent		Weeds		Pests		Labor	Yield	Profit	Farmer	Land
Crop	Year	Site	Grp	Ma	Fer	Sa	Her	Ins	Fun	days ra[-1]	kg rai[-1]	Bt day[-1]	Bt day[-1]	Bt rai[-1]
Field Crop Production														
Soybean – upland	1997	1.1	Ka	X		X		X		9	160	53	158	1,193
	1997	1.2	Ka	X		X				32	528	130	172	5,012
	1997	1.3	Ka	X		X				29	160	15	20	(22)
Soybean – upland	1998	4.1a	Th	X		X		X		14	192	54	62	487
	1998	4.2	Th	X		X				22	176	7	31	302
	1998	4.3	Th	X		X		X		16	192	45	88	1,064
Soybean – paddy	1998	4.1a	Th	X		X		X		19	240	53	82	1,17
	1998	4.1b	Th	X		X		X		13	240	52	138	1,540
	1998	4.2	Th	X		X		X		19	256	43	92	1,310
	1998	4.3	Th	X		X		X		13	224	76	84	812
Maize – feed	1997	1.1	Ka	X		X				8	496	(6)	279	1,882
	1997	1.2	Ka	X		X				12	208	21	72	633
Maize – sweet	1997	1.3	Ka	X		X				22	1,104	32	50	622
Maize – feed	1998	3.2a	Hm	X		X				16	512	63	74	930
	1998	3.2b	Hm	X		X				14	432	75	78	846
Maize – feed	1998	4.1b	Th	X		X				10	544	5	101	907
	1998	4.2	Th	X						10	608	66	257	2,380

Analysis of profitability using international prices indicates a net tax effect on both soybean and maize, and the effect may actually be getting worse since the economic crisis. Moreover, the longer-term degree of change and scale of impact of new cultivars and contract farming being introduced by large agro-industry operations remain to be demonstrated.

In terms of environmental concerns, chemical usage on field crops appears to usually be limited to fertilizer and herbicide in Karen communities, but insecticide applications also appear widespread on soybean in Thai communities. From a forestry point of view, expansion of soybean has been associated as a key element both in deforestation and in efforts to return forest fallow lands to permanent forest cover. During the mid-1980's, introduction of upland soybeans was associated with a surge in deforestation as lowland Thai villages expanded upland fields up hillsides of major valleys into sloping reserved forest watershed lands. This resulted in much concern by the forest department, and a new generation of projects focused on natural resource management and forest conservation. Upland soybean production began entering midland Karen villages as conservation policies and programs began urging them to stop forest fallow shifting cultivation. A major local response to this situation has been use of upland soybean in crop rotations with upland rice to help prevent rice yield decline in fixed fields and to generate income for chemical inputs; implications of the shift to maize are not yet clear.

c. ***Vegetable Production***

The highest levels of profitability, at both farmgate and international prices, are attained in vegetable production, which is composed of three basic types:

(1) Major Lowland Vegetables

Intensive lowland vegetable production, represented here by shallots grown in both rainy and dry seasons, was the most profitable option for lowland agriculture found in Mae Chaem. However, shallots – along with many other lowland vegetables – have a history of boom-and-bust cycles that over-produce or under-produce relative to available market demand.

Table 8. Major lowland vegetable crop production

		Location		Inputs & Technology							Product	Farmer	Internat Prices	
		Vill	Eth	Nutritent		Weeds		Pests		Labor	Yield	Profit	Farmer	Land
Crop	Year	Site	Grp	Ma	Fer	Sa	Her	Ins	Fun	days ra^{-1}	kg rai^{-1}	Bt day^{-1}	Bt day^{-1}	Bt rai^{-1}
Major Lowland Vegetable Crops														
Shallot	1998	4.1a	Th	X	X		X	X	X	18	2,176	463	509	8,854
	1998	4.1b	Th	X	X		X	X	X	14	1,984	328	466	6,194
Shallot (dry)	1998	4.1a	Th	X	X		X	X		24	2,432	186	225	5,079
	1998	4.1b	Th	X	X		X	X	X	16	2,272	382	798	12,762

KEY: Th=Northern Thai, Ka=Karen, Hm=Hmong, Ma=manure, Fer=fertilizer, Sa=salt, Her=herbicide, Ins=insecticide, Fun=fungicide

Analysis using international prices indicates that profitability would benefit from prices more in tune with international markets, since the effect of depressed output prices are greater than net fertilizer subsidies. And, since production of these crops involves high levels of chemical use, environmental concern would be expected to focus on stream pollution and water use, although such issues with lowland crops are not yet very visible in the political arena.

(2) Major Highland Vegetables

The most profitable crops are major highland vegetables, represented here by cabbage, carrot and potato, which are primarily grown in ridge-dwelling ethnic Hmong communities, with some spread effects into neighboring higher-altitude ethnic Karen villages. While cabbage has been the most widely produced highland vegetable in recent years, carrots are currently the most profitable, and potato shows promise if disease can be controlled. As substantial market and environmental risks are involved, capital reserves are required to maintain operations.

Analysis using international prices reveals that if producers of these crops could have access to input and product prices more in tune with international markets, profits would be even higher. This is because the net subsidy seen in the price of fertilizer is dwarfed by the net tax effect on output prices received by farmers. These depressed prices may relate to excessive profits or postharvest losses somewhere in the marketing chain, which is largely independent of 'normal' markets and thus fairly difficult to investigate, or more simply to over-production relative to the commodity flows that the marketing system can handle.

Perhaps a more important issue under current circumstances relates to the actual and/or perceived environmental concerns associated with highland vegetable production. Perceived impacts with political importance include: (a) stream pollution by extensive use of pesticides, herbicide and chemical fertilizer; b) reduced dry season stream flow, increased rainy season storm flows, and accelerated downstream sedimentation due to deforestation associated with creation of highland fields in hill evergreen forest zones; c) reduced dry season stream flow due to water use by sprinkler irrigation systems in highland vegetable production areas.

Table 9. Major highland vegetable crop production

		Location		Inputs & Technology							Product	Farmer	Internat Prices	
		Vill	Eth	Nutritent		Weeds		Pests		Labor	Yield	Profit	Farmer	Land
Crop	Year	Site	Grp	Ma	Fer	Sa	Her	Ins	Fun	days rai^{-1}	kg rai^{-1}	Bt day^{-1}	Bt day^{-1}	Bt rai^{-1}
Major Highland Vegetable Crops														
Cabbage	1998	3.2a	Hm	X	X		X	X	X	20	2,688	266	939	18,603
	1998	3.2b	Hm	X	X		X	X	X	22	2,304	26	726	15,232
Cabbage (dry)	1998	3.2a	Hm		X		X	X	X	13	2,352	263	792	10,007
	1998	3.2b	Hm		X		X	X		24	2,176	130	386	8,680
Cabbage	1998	3.1	Ka	X			X	X		42	2,304	71	405	16,498
Cabbage	1998	4.1b	Th		X		X	X	X	17	1,904	220	737	12,359
Carrot	1998	3.2a	Hm		X		X	X	X	21	3,232	725	2,535	52,422
	1998	3.2b	Hm		X		X	X	X	34	2,816	246	1,309	43,501
Carrot (dry)	1998	3.2a	Hm	X	X		X	X	X	36	2,768	246	1,227	43,652
	1998	3.2b	Hm	X	X		X	X	X	44	2,512	209	900	38,556
Carrot	1998	3.1	Ka		X					20	3,360	765	2,798	55,093
Potato	1998	3.2a	Hm		X		X		X	30	1,184	107	19	(11)
	1998	3.2b	Hm		X				X	10	1,472	639	755	7,347
Potato (dry)	1998	3.2a	Hm		X				X	22	1,008	119	(158)	(3,685)

KEY: Th=Northern Thai, Ka=Karen, Hm=Hmong, Ma=manure, Fer=fertilizer, Sa=salt, Her=herbicide, Ins=insecticide, Fun=fungicide

(3) Highland Specialty Vegetables

Specialty highland vegetables are another agricultural option under some conditions, as represented here by lettuce, green pepper and pumpkin produced in Wat Chan for the Royal Project Foundation (RPF). Profitability is quite high by local standards, but production requires transportation infrastructure and fairly elaborate extension, processing and marketing support. Some non-RPF specialty crops, such as taro and ginger, currently show very low profitability.

Table 10. Highland specialty vegetable crop production

		Location		Inputs & Technology							Product	Farmer	Internat Prices	
		Vill	Eth	Nutritent		Weeds		Pests		Labor	Yield	Profit	Farmer	Land
Crop	Year	Site	Grp	Ma	Fer	Sa	Her	Ins	Fun	days ra^{-1}	kg rai^{-1}	Bt day^{-1}	Bt day^{-1}	Bt rai^{-1}
Specialty Highland Vegetable Crops – Royal Project Foundation														
Pumpkin	1997	2.1	Ka	X	X				X	23	960	288	704	15,534
Lettuce	1997	2.1	Ka	X	X		X			35	992	203	521	17,433
Green pepper	1997	2.1	Ka	X	X		X		X	44	1,264	268	400	16,985
Gladiolas	1997	2.1	Ka	X	X				X	108	11 kHd	94	139	14,134
Specialty Highland Vegetable Crops – Other														
Taro	1997	2.1	Ka	X	X					41	528	28	78	1,966
Ginger	1997	2.1	Ka	X	X				X	33	336	(130)	23	(6)

KEY: Th=Northern Thai, Ka=Karen, Hm=Hmong, Ma=manure, Fer=fertilizer, Sa=salt, Her=herbicide, Ins=insecticide, Fun=fungicide

As with other vegetable crops, it appears that profitability would be much higher if prices were closer to those in international markets. But the apparent farmgate price depression needs to be examined carefully. These commodities are produced and marketed in association with the RPF, which has a range of retail outlets selling its 'Doi Kham' brand name. While this is an operation with extremely interesting potential, the degree to which farmgate prices interact with postharvest losses, grading issues, and its transport, processing and marketing capacity raises some interesting questions regarding further development of these production operations.

In terms of environmental concerns, while fertilizer and some herbicide and fungicide are used on these crops, overall chemical usage appears considerably lower than other vegetable production categories. Nevertheless, some still perceive these activities as using high levels of agricultural chemicals. Thus, as part of their efforts to encourage more environmentally friendly practices, RPF has been encouraging diversification into fruit trees, often in agroforestry style, and is considering other products from native species of plants in local landscapes.

d. *Home Gardens & Fruit Tree Agroforestry*

In some parts of Mae Chaem, complex home gardens are prominent features of lowland Thai agroecosystems. Since they were too complex for PAM studies, a small study led by Sittichai Ungphakorn (RFD) investigated a sample of 24 home gardens.[24] Gardens contained from 21 to 76 plant species, and included both cash and in-kind costs. All households received in-kind benefits from their gardens, and 80 percent also received cash income. While cash incomes exceeded cash costs for only 16 percent, in-kind benefits exceeded in-kind costs for 92 percent, with only 8 percent showing a net loss. On average, home gardens accrued a net cash deficit of Bt 1,820 hh^{-1} yr^{-1}, but an in-kind surplus valued at Bt 6,860 hh^{-1} yr^{-1}, resulting in an average net benefit of Bt 5,040 hh^{-1} yr^{-1}

In order to help build basic knowledge useful for efforts for exploring the potential for further development of fruit tree agroforestry in Mae Chaem, a doctoral study was conducted by Brad Withrow-Robinson in association with the CMU Multiple Cropping Center. Based on study of results of fruit tree promotion in Mae Taeng by the Sam Mun Highland Development Project, a preliminary taxonomy for classifying fruit tree agroforestry practices was developed[25] as one part of a broader analysis. Local approaches to fruit tree agroforestry were along a continuum of gradually changing and overlapping characteristics from expansion of mixed plantings similar to home gardens, to orchards appearing more similar to lowland commercial fruit operations. [26] Development of commercial fruit tree agroforestry appears to go through various stages that may require different types of extension services and support from development programs.

e. ***Natural Plant Products***

Although natural plant use is an important part of livelihoods in mountain communities, the subject was too complex for our core economic assessments. An M.Sc. study[27] conducted by Patcharin Nawichai, under the guidance of Dr. Benchaphun Ekasingh, provided a first step in improving our quantitative understanding of wild plant use, including patterns and sources of gathering, and trends in their abundance. [28] This study of 3 Karen villages in Wat Chan, found numbers of useful plant species consistent with an ethnobotany study in three villages further south (see biodiversity section). Useful wild plant species were grouped into 5 categories: food, fodder, dyes, medicine and fuelwood. Table 11 summaries findings on species and per capita quantities of products in each category, by gender. Women collected more species and amounts than men in all categories other than medicinals. While food included more species, fuelwood was collected in largest quantities. The most popular locations for wild plant collection by women were near their village, and particularly near streams; men would often travel farther.

Table 11. Estimated number of species and per capita amounts of wild plants used

	Food		Fodder		dyes		Medicine		Fuelwood		Total
	spp	*amt*	*spp*	*amt*	*spp*	*amt*	*spp*	*amt*	*spp*	*amt*	*amt*
	no.	kg yr^{-1}	no.	kg yr^{-1}	no.	kg yr^{-1}	no.	kg yr^{-1}	no.	kg yr^{-1}	kg yr^{-1}
Women	117	129	9	456	10	13	44	3	17	2,368	2,969
Men	47	50	5	115	3	1	49	8	15	76	250
Total amt:		179		571		14		11		2,444	2,219

While most wild plants are gathered for household use, 40 percent of women and 16 percent of men also reported sales of wild plant products. Women collected and sold wild flowers, mushrooms and nuts, whereas men collected and sold primarily wild vegetables and some mushrooms. Highest incomes were from flowers and mushrooms, which in one village yielded an average of about Bt 1,260 hh^{-1} yr^{-1} ; in the same village total wild plant sales accounted for an average 7 % of total household cash income. While collection of food and fodder was unrelated to relative wealth status, poorer households had relatively higher levels of representation in collection of dyes, medicine and fuelwood.

Villagers perceive that the diversity and quantities of wild plants are decreasing because of over-collection and destruction of habitat by fire, cattle and deforestation. They identified 4 species as no longer available near the village, 6 species that are drastically reduced but still present, and 11 more species that have begun to noticeably decrease. At least 16 wild plant species have been domesticated through their integration into home gardens.

D. Biophysical & Economic Trade-offs Among Mountain Land Use Practices

Drawing on this information, we are summarizing major relative costs and benefits of these land use practices, and examining trade-offs among them. The preliminary 'ASB matrix' presented in Table 12 is an initial product of these efforts. Enough cells have now been filled in to begin seeing major patterns in the characteristics of various land use practices.

The following brief summaries compare various land use practices to a hill evergreen forest baseline. Mature hill evergreen forest has maximum values for many characteristics deemed most valuable from an environmental point of view. It is also highly valued as a site for many agricultural practices, and its conversion is one of the most hotly contested areas in policy debates regarding forest protection and needs of local mountain minority communities. The first four categories roughly follow a gradient of increasing agronomic intensification, and a decreasing role of natural

Table 2. Key biophysical and economic properties of component Land use practises in Mae Chaem (Preliminary ASB matrix)

	Methane	Carbon Stock		Biodiversity		Agro-Sustainability Factors				Main Crop		Private	Social	
	Absorption	Above	Below	spp	PFC	Soil BDens	Fertility	Weeds	Pests	Yield	Labor	Profit	Profit	Land
	gm/ha/day	ton/ha	ton/ha	no.	index	gm/cc	inputs used			ton/ha	day/ha	$/day	$/day	$/ha
Natural Forest														
Hill E-G max	4.8	253	122	69	703	0.78								
Hill E-G ave	2.1	118	94	56	562	0.93								
Hill Pine	1.6	79	73	55	575	1.08								
Mixed Deciduous				82		1.10								
Dry Deciduous	2.4	60	60	37	359	1.27								
Rice – Traditional Community-Managed Rotational Forest Fallow Sequential Agroforestry System														
10-year cycle	4.9	51*	107*	63**	513**	1.10	-	labor	-	0.3*	29*	1.43	1.22	2*
6-year cycle	5.0	16*	60*	64**	498**		-	labor	-	0.2*				
+ old trees		54*	60*			1.02	-	labor	-					
Rice – Household-Managed Fixed Field Systems														
hh 5-year 'priv' fallow	5.7						-	labor	-	0.2*	16*	1.52	1.47	5*
hh 3-year rotate		3*	48*	43**	445**	1.22	fert	lab+herb	-	0.9*	116*	0.75	0.72	(49)*
Perm Field	2.4	2	22	33	249	1.33	fert	lab+herb	±chem	1.4	213	0.24	(0.01)	(203)
Rice – Flooded Paddy	(689.0)			30	192		fert	lab+herb	±chem	3.5	219	1.79	1.38	28
Field Crop Production														
Soybean						1.33	fert	lab+herb	±chem	1.5	117	1.51	2.65	230
Maize	2.4	7	92			1.40	fert	lab+herb	-	3.5	82	1.23	3.72	209
Vegetable Crop Production														
Cabbage/Carrot							fert	lab+herb	chem	16.1	166	8.49	33.13	5,107
Lett/GrPpr/Pumpkin		0.3	82				fert	lab±herb	±chem	6.7	212	7.23	15.47	2,973
Taro/Ginger							fert	labor	±chem	2.7	232	(1.47)	1.45	175
Shallots				7	58	1.43	fert	lab+herb	chem	13.9	113	9.70	14.27	1,468
Simultaneous Agroforestry														
Fruit/veg alley cropping	2.3	5	153			1.19								
Home Garden				47										
Coffee w/shade		51	127	30	216	1.12								

vegetation and regeneration processes. The final category includes agroforestry alternatives for which we have limited data.

1. Community-Managed Rotational Forest Fallow Sequential Agroforesty.

- **8-10-year forest fallow cycle.** This system can be expected to reduce time-averaged above-ground carbon storage by about 50 percent, along with reduced basal area, average forest canopy height, and timber stocks, but there is much less impact on below-ground carbon storage. In return, land users can conduct subsistence rice production that earns modest but reasonable returns to their labor relative to local wage rates, along with other subsistence crops and useful natural plants are integrated into the system. Little overall impact can be expected on methane absorption rates, water infiltration or stream flow discharge buffering capacity relative to natural forest, although total annual water yield may be reduced somewhat by rapidly growing forest during early regeneration stages. Biodiversity of the most mature stages of forest regeneration should be comparable to natural hill evergreen forest. As no fertilizers, herbicides or pesticides are used, pollution from agricultural chemicals should pose no problem.
- **5-6-year forest fallow cycle.** This system appears to reduce overall above-ground carbon by 50 to 85 percent, depending on the number of large trees left in cropped fields, along with a further reduction in average canopy height; up to 40 percent of below-ground carbon stocks may be lost. Land users obtain rice and other subsistence crops and natural plants. The system appears to remain agronomically sustainable, but it appears returns to labor would be somewhat lower than longer fallow conditions. There should still be relatively little overall impact on methane absorption rates or water infiltration relative to natural forest, and impact on stream flow discharge buffering should be modest. Total water yield may be reduced by the large proportion of forest fallow area in rapid growth stages. Biodiversity of the most mature stages of forest should still be relatively similar to natural forest, and absence of chemical use should preclude associated water pollution hazards.

2. Household-Managed Fixed-Field Fallow Rotations.

- **5-year 'private' fallow.** The general biophysical properties of this system should be quite similar to those of community-managed 5-6 year forest fallow cycle (above), with the possible exception of increased fragmentation of the landscape. The example studied had relatively higher returns to labor, due to less labor employed in the system. Since there is no agricultural chemical use, there should be no water pollution hazards from this system.
- **3-year fallow rotation.** This system appears to reduce above-ground carbon storage by 97 percent, and below-ground carbon by about half. Species richness in the third year appears to

be reduced by about one-third, although plant functional complexity remains quite high. Soil bulk density appears to increase to levels similar to dry dipterocarp forest, implying reductions in water infiltration and methane absorption rates, and higher risk of soil erosion. Evidence also indicates modest reduction in stream flow discharge buffering. Land users still obtain subsistence rice, other subsistence crops and natural plant products, but returns to labor have dropped to at least 25 percent below modest local wage rates. This is partially due to chemicals needed to help maintain soil fertility and suppress weeds, which also begin to introduce risks of chemical pollution in local streams.

3. Fixed field Upland Crop Production.

- **Paddy rice.** Production of rice in flooded paddy provides higher returns to labor than any forms of upland rice production. And, with relatively high yields from fields requiring no fallow rotations, paddy is also the most land-saving form of rice production. There are, however, some environmental trade-offs. Paddy plant biodiversity is roughly similar to upland rice fields, with about half the species richness and functional complexity of forest. Watershed impacts are mixed. While paddy has high levels of evapotranspiration from leaf and standing water surfaces, paddies function as a physical filter by trapping sediment in streams diverted to flow slowly through paddy areas. But, since paddy production usually uses chemical fertilizer, herbicides, and sometimes pesticides, it is a water pollution hazard if chemicals are not properly managed. From a climate change perspective, very little above-ground carbon storage remains, and flooded conditions result in massive release of methane.
- **Upland rice.** This practice appears to reduce carbon storage by 98 percent above ground, and about 80 percent below ground. In terms of biodiversity, species richness and plant functional complexity are reduced by at least 50 percent relative to natural forest. Soil compaction increases bulk density to levels comparable to other types of permanent fields, resulting in lower levels of methane absorption, water infiltration and stream discharge buffering capacity. Use of chemical fertilizers, herbicides, and some pesticides result in potential water pollution hazards. Use of purchased inputs, fairly high labor use, and high vulnerability to damage in years of low rainfall, result in returns to labor that are less than half of local wage rates. Without the mild effect of fertilizer subsidies and rice price support, this system would have average returns to labor near zero. From financial and economic points of view, this was clearly the poorest performing agricultural practice studied.
- **Soybeans and maize.** Commercial production of these crops on fixed upland fields has biophysical impacts very similar to those for upland rice. Relatively high below-ground carbon storage in our

sample maize field most likely relates to recent establishment of maize production there. However, these crops provide returns to labor that are competitive with local wage rates, and returns would apparently be increased from 1.6 to 3 times current levels if farmgate prices were more closely aligned with those in international markets. As with other fixed field production practices, substantial use of agricultural chemicals poses potential water pollution hazards if not managed properly.

4. Intensive Vegetable Crop Production.

- **Highland major vegetables.** As these crops are usually grown in hill evergreen forest areas, impacts appear to include nearly complete loss of above-ground carbon storage, and very major reduction in plant biodiversity. While loss of below-ground carbon storage, and increased soil bulk density, may depend on how much manure and mulch are used in these crops, sample sites indicate significant impacts, including substantial reduction in stream discharge buffering capacity. Total water yield may be further reduced by sprinkler irrigation. Heavy use of agricultural chemicals introduces pollution hazards if not managed carefully. In return, however, returns to labor are about 4 to 6 times higher than those provided by rice and field crops, making this by far the most profitable major agricultural practice currently found in the Mae Chaem watershed. While significant market risks are also associated with these crops, overall profitability remains very attractive for those with sufficient capital.
- **Highland specialty vegetables.** General impacts on carbon storage and biodiversity appear similar to those of highland major vegetables. Impacts on methane absorption and water infiltration are somewhat mitigated by use of manure and mulch, which helps maintain higher soil carbon and lower soil bulk density; sample fields were located on very gentle slopes or terraces next to paddy fields. Total water yield may be somewhat reduced by irrigation, which is often by hand. While chemical fertilizer is usually used, fertilizers and pesticides are used less frequently. At current farmgate prices, returns to labor are high — 85 percent of top-earning highland major vegetables. There can be significant fluctuations in returns to labor, however, due to both market and environmental risks.
- **Lowland vegetables.** General biophysical impacts appear similar to highland specialty vegetables; the most significant difference is regular pesticide use. Returns to labor were about 30 percent higher than highland specialty vegetables, but these products are often associated with 'boom-and-bust' production cycles. It should be kept in mind, however, that comparison with hill evergreen forest is not really appropriate for this type of land use, since it occurs in zones more likely to have been covered with mixed deciduous forest.

5. Simultaneous Agroforestry Alternatives.

- **Complex agroforests.** While shortage of data prevents full assessment of this approach, there are indications that above-ground carbon storage in complex agroforest can be at least 50 percent of average hill evergreen forest, with little reduction in below-ground storage. Biodiversity in coffee with forest shade was reduced by about 50 percent, but values may vary in other forms of agroforest; some lowland home gardens have species richness levels close to hill evergreen forest. Soil bulk density appears similar to natural mixed deciduous forest, implying only modest impact on methane absorption, water infiltration and stream discharge buffering capacity. While profitability data is not yet available in a comparable form, high returns to labor in 'miang' type systems modified to include a range of tree crop products are known in some areas outside the Mae Chaem watershed.
- **Simple agroforestry.** More simple forms of agroforestry, such as small, widely-spaced fruit trees intercropped with vegetables, appear to offer some mitigation of impacts on soil bulk density and possibly below-ground carbon. Otherwise, biophysical impacts appear to be similar to the vegetable components of the system. Profitability data is not yet available.

E. Agroforestry Landscape Patterns.

While the above type of information begins to help clarify a range of important costs, benefits and trade-offs associated with various land use practices, it does not yet directly correspond with positions being taken in public policy debate associated with these issues. If we assume arguments to forcibly relocate all mountain minority communities from their current locations into the lowlands are unrealistic and not logistically feasible (or morally reasonable), then debate really centers more on the relative balance of permanent agriculture, forest fallow agriculture and various forms of permanent forest in mountain area agroforestry landscapes.

Thus, the following sections summarize implications of our research findings for four different 'scenario' approaches to upland land management patterns, followed by a brief summary of the overall implications of paddy land as a factor in these scenarios.

1. Traditional Forest Fallow Rotations and Permanent Forest Scenario

Traditional rotational forest fallow agroforestry manages crop and forestry components 'sequentially' within a landscape that also includes areas of permanent forest, and often rice paddies. As long as forest fallow systems maintain cycles between 5 to 10 or more years in length, they appear to offer reasonable returns to producer labor with relatively modest environmental impacts. If cycles on the shorter end of this range maintain some large trees in their cleared and cropped fields, the greatest environmental impact compared to relatively mature hill evergreen forest appears to be a roughly 50 percent overall decrease in carbon storage, with an associated reduction in standing timber stocks and average forest canopy height. As these systems require fairly extensive areas of land, a relatively large portion of the landscape would be affected in this manner. It is worth noting, however, that in order to produce equivalent amounts of upland rice, a 10-year cycle yielding 3 tons ha^{-1} would occupy less total land than a 5-year cycle yielding 1 ton ha^{-1}! In either case, these systems appear to be agronomically sustainable without purchased inputs, and provide watershed and biodiversity services similar to natural forest. One exception may be a modest loss in total water yield due to higher evapotranspiration rates of young rapidly growing forest fallow compartments. Average values of environmental characteristics would increase according to the relative portions and strategic locations of the landscape that are set aside and managed as permanent forest.

As cycle length drops below 4 years, crop components begin requiring chemical inputs to help maintain soil fertility and suppress weeds, and returns to producer labor drop below the average implicit local wage rate. Nearly all of the above-ground carbon storage is lost, plant species richness is reduced, and increased soil compaction begins to reduce methane absorption, water infiltration and stream discharge buffering capacity. In principle, most of these negative impacts might be mitigated if well-located permanent hill evergreen forest occupies an increased proportion of the landscape. Factors not mitigated by increased permanent forest include low returns to labor and the need to manage agricultural chemicals to avoid water pollution, but increased use and/or sale of forest products might help reduce poverty.

2. Fixed Field Upland Crops and Permanent Forest Scenario.

This approach segregates intensified fixed field agriculture from the forest, in order to reduce land use pressure on forest areas. In this situation, upland rice and field crops are produced continuously on fixed upland fields, which would require some rotating of crops among fields to prevent yield decline in upland rice. As all fallow areas would be returned to permanent forest cover, the relative proportion of permanent forest in the landscape would be increased relative to options under the forest fallow rotation scenario, above.

For lands placed in permanent agriculture, most all above-ground carbon storage and much below-ground storage would probably be lost, plant biodiversity would be reduced by at least 50 percent, and increased soil compaction would result in increased risk of soil erosion, as well as relatively low methane absorption, water infiltration, and stream discharge buffering. Consolidation of these fields in one or a few large areas can result in long slopes of open fields and accelerated soil degradation. Agricultural chemicals would be used to help maintain soil fertility and suppress weeds, and perhaps pests. Since upland rice produced under these conditions has very poor returns to labor, whereas field crops appear to offer returns close to the implicit local wage rate, overall returns to labor would depend on the balance between upland rice and field crops — the larger the proportion of agricultural land planted to upland rice, the more overall returns to labor would be expected to fall below those of other alternatives.

Increased proportions of the area under forest would be expected to offset impacts of agricultural areas on carbon storage, methane absorption, plant biodiversity and watershed impacts, especially if forest is strategically well located in a landscape mosaic. Use of agricultural chemicals would need careful management, and conservation farming practices may be needed in some fixed agricultural fields. This scenario presents the most difficult challenge for mitigating effects of low returns to agricultural labor, and thus rural poverty. Products from expanded areas under permanent forest may be one attractive option to help in this regard.

3. Intensive Vegetables and Permanent Forest Scenario.

In this scenario, segregated fixed agricultural fields are planted to intensive commercial vegetable crops, rather than subsistence upland rice and lower-value field crops. Impacts in agricultural fields include loss of most all above-ground carbon storage and plant species diversity, relatively high soil compaction and soil erosion risk, and relatively low methane uptake, water infiltration, and stream discharge buffering capacity. Total water yields may be reduced where use of sprinkler irrigation is extensive. Returns to labor, however, are very attractive: at current prices, all 3 types of vegetable production appear to offer returns at least four times higher than paddy rice. Although these crops are also subject to fairly high levels of production risk, due to both market and environmental variability, financial incentives appear quite strong.

Examples of practices in some types of vegetable production – such as those under the RPF — that could mitigate some potentially negative environmental effects include: 1) use of manure and mulch could reduce soil erosion risk and effects associated with soil compaction; 2) reduced frequency of pesticide use; 3) simple intercropping of fruit trees could help increase carbon storage and decrease soil compaction; 4) location of vegetable fields on gentle slopes or terraces, and/or integration of conservation farming practices.

As with the previous scenario, increased areas under forest could be expected to offset impacts of agricultural areas on carbon storage, methane absorption, plant biodiversity and watershed impacts, especially if they are strategically well located in the landscape. Agricultural chemical use and irrigation may still need careful management. This scenario presents the most difficult challenge for managing environmental impacts of intensive agriculture, and for identifying sufficient incentives to maintain permanent forest components of the landscape.

4. Agroforest and Permanent Forest Scenario.

This scenario provides a 'simultaneous' agroforestry alternative for integrating agriculture and forestry components in the landscape, without a shifting cultivation component. While current examples in Mae Chaem appear limited to coffee under natural forest shade and complex lowland homegardens, examples outside Mae Chaem include 'miang' tea agroforests and their transformed variants, and various mixed fruit-based variations that are locally significant in different areas of northern Thailand. Many 'miang' tea agroforests and some others also integrate a livestock component, usually centered on cattle grazing/browsing.

Although data is still incomplete for elements of this scenario, we could expect above-ground carbon storage to be 50 percent or more of that found in average hill evergreen forest, with perhaps relatively little loss in below-ground storage. Plant species richness would probably be at least half that of natural forest, and possibly more. Soil compaction would probably be rather modest, resulting in only mild effects on methane absorption, soil erosion risk, water infiltration and stream discharge buffering. As there is usually no irrigation or areas where young forest is in rapid growth stages, impact on total water yield should not be great. Use of agricultural chemicals is usually absent or modest, but may increase in some cases. Although we do not yet have data that can allow us to assess profitability in a PAM format, we do have anecdotal evidence that profitability can range from levels reasonably competitive with implicit local wage rates, to quite impressive levels.

The portion of a landscape occupied by these systems would likely vary, but would probably be greater than portions used for more intensive forms of segregated fixed field agriculture. This may be mitigated, however, by their lower levels of environmental impact. Moreover, efforts to promote this scenario would need to emphasize land security and other incentives to encourage further expansion and refinement of this approach.

5. Wild Card: The Rice Paddy Component

Paddy rice is referred to as a 'wild card' because it can be integrated as a component of all the above scenarios. The relative proportion of area converted to paddy land is usually limited by terrain and geographical considerations. In areas where paddy has been able to expand, it has greatly reduced needs for upland rice and its associated environmental impacts. It also provides a fairly reliable subsistence rice base, from which farmers can diversify with more confidence into more risky commercial crop activities.

Although paddy rice provides reasonable returns to labor, and minimizes land area needed for rice, it may also increase water use. And, while it can help filter sediment from streams diverted to paddy areas and open fields immediately upslope, use of agricultural chemicals can be a pollution hazard if not managed carefully. Methane emissions are another trade-off that focuses specifically on flooded paddy conditions.

Another option is to further intensify paddy use, through combinations of: (a) increasing main season crop yields; (b) a second rice crop where dry season stream flow is sufficient; (c) other cash crops grown in paddies after rice. While increased water use is an obvious trade-off for the second and third approaches, some argue that this could be justified by improved stream discharge buffering and dry season stream flow, at least where increased paddy production would be associated with increased areas under permanent hill evergreen forest. More specific studies of the water use trade-offs associated with these options may be warranted.

F. Institutional Dimensions of Local Landscape and Conflict Management

Clearly, there is no single 'right' landscape management scenario that will provide the best outcome under all conditions. Thus, the next step in improving the policy focus of these assessments, involves integration of institutional issues and processes for managing land use and associated conflict into an overall approach for negotiating trade-offs associated with specific agroforestry landscapes under the range of actual local conditions found in the region.

1. Approaches for Monitoring Impacts and Managing Conflict

Major issues featured in the debate and conflict over natural resource management (see section A, above) include perceived impacts of changing highland and midland land use practices and patterns on mountain forest resources, and especially on the volume, timing and quality of water in streams flowing to downstream areas. Core positions in this debate include:

- Advocates of 'downstream' views go as far as calling for forced relocation of all communities from mountain watersheds, so they can be returned to forest. Growing populations and changing agricultural practices in upper watersheds are claimed to be devastating watershed functions, resulting in downstream rainy season flooding and sedimentation, dry season drought, and water pollution from toxic agricultural chemicals used in highland cash crops. Loss of forest biodiversity is also now invoked by the expanding conservation coalition.
- Advocates of 'upstream' views go as far as denying major impacts on watershed functions, and claiming downstream water problems are due to expansion and intensification of downstream land use. Downstream people do not understand minority agroecosystems and practices, and downstream arguments are only a cover for state-sponsored expropriation of local community lands in upper watersheds. They counter ethnic overtones of downstream arguments with accusations of ethnocentrism, racism and ethnic cleansing of upland forests.

Numerous impassioned presentations and articles advocating one side or the other have been featured in both national and international events and media, and major confrontations have occurred in 'hot spots' such as the Chom Thong area just across the eastern ridge of the Mae Chaem watershed. Awareness of these issues and associated tensions are widespread and increasing in most upper tributary watersheds of northern Thailand.

While tensions and conflict over land use in upper tributary watersheds are increasing, much responsibility for dealing with these issues is being shifted to local institutions. The 1997 national constitution and recent laws provide new mandates and stronger roles for locally elected Tambon Administrative Organizations (TAO). As reforms expand responsibility and authority for local institutions in managing natural resources and associated conflict, many rural development and natural resource management projects are seeking to strengthen capacity of TAO and other local institutions. ASB-Thailand is adapting its research to support these efforts by collaborating with local projects, watershed management networks, and TAO to enhance their capacity to manage conflict related to land use and upstream-downstream relations:

a. Land use conflict

As in many other upper tributary watersheds, nearly all land in Mae Chaem is classified as reserved forest, 90 percent is class 1 or 2 protected watersheds, and substantial areas are within still expanding national park boundaries. Only relatively small areas of paddy land, primarily in lowland Thai areas, have official land tenure recognition. All other agricultural and agroforestry land use is informal, and technically illegal. While informal local land use institutions have provided a basis for managing community land for generations, they are vulnerable to pressure and encroachment from more powerful outside forces. For example, forest fallow and protected forest areas of long-established midland Karen communities have become targets for use by neighboring villages, often of other ethnic groups, or for government forest programs.

Despite the legal status of these lands, various projects have sought to help address growing land use conflict issues by collaborating with local communities in demarcation of local land use zones that seek a reasonable compromise aimed at meeting needs of both local livelihoods and national society, in a process often known as participatory land use planning.[29] Tools such as 3-dimensional models have been used to facilitate and clarify these negotiations in many areas, and communities have worked with projects to articulate and enforce local rules and regulations aimed at implementing these agreements. However, the absence of a legal framework for their recognition remains an important obstacle for TAO and other local institutions to help strengthen security and prevent encroachment by more powerful outside forces. Two recent efforts have sought to provide a basis for more official recognition:

- In 1993 the government assigned 44 million rai of reserved forest land to the Land Reform Office for them to allocate land 'suitable for agriculture' to individual households; remaining land is to be returned to forest department jurisdiction. Since this process has no mandate to consider local land management institutions or land use zoning efforts, and it only allocates fixed fields to individual households, it effectively seeks to ignore landscape mosaic agroforestry issues, and to destroy any existing community-level land management institutions along with all forms of shifting cultivation. Progress is slow, but continuing.
- Since 1990, various government officers, academics and NGOs have sought passage of community forestry legislation that would provide a legal basis for community managed lands within reserved forest areas. Passage of a community forestry law has been delayed by debate among interest groups over whether community forestry or agroforestry should be legally allowed within national parks, wildlife sanctuaries or protected watersheds. Efforts to pass a compromise version have been revived by the current government, however, and its passage in the not too distant future is a distinct possibility. In principle, this could provide the legal basis for a process that could recognize local land use zoning agreements and landscape mosaic agroforestry management practices. Transparency and accountability in implementing and enforcing land use agreements, is likely to be a major concern of skeptics.

While some observers have sought to characterize local land use zoning agreements as an effort by the state to construct boundaries that would 'territorialize', and thus confine, limit and devalue local institutions, most communities in Mae Chaem appear to support demarcation of boundaries that would increase their security. Their concerns tend to focus on the nature of the decision making process and the degree to which they are actually allowed to participate.

Thus, ASB-Thailand collaborated with local projects in testing geographic information system (GIS) tools to articulate local land use zoning in a form that could provide a basis for land use agreements, and increase transparency and accountability in monitoring compliance with agreements. Initial efforts focused on several sub-watershed areas in Mae Chaem, where we now have detailed digital information on terrain, settlements, infrastructure and historical land use change, and are digitizing local land use zoning maps where they have been developed through participatory land use planning processes. We are also working with CMU colleagues to explore approaches for identifying areas with high risk for erosion, flooding, etc, as well as use of remote sensing to monitor actual land use against local land use plans.

b. Upstream-downstream conflict

Two additional lines of ASB-Thailand activity have explored development of knowledge and tools that can help improve efforts to address upstream-downstream issues in the context of the new constitution and changing approaches to local governance:

(1) Local Knowledge

A preliminary study led by Dr. Pornchai Preechapanya investigated local ecological knowledge related to watershed management and the underlying interactions of biotic with non-biotic components. Particular focus was on how plants and animals are related to microclimate and processes of water cycling and soil erosion. The study employed techniques for eliciting, recording and accessing local knowledge that are being developed and refined by a research group at the University of Wales, Bangor,[30] including use of their WinAKT software. Some initial findings[31] have been incorporated into a Thai-language publication on folk knowledge about agroforestry in mountain watershed areas.[32], which includes discussion of rotational forest fallow agroforestry, 'jungle' tea agroforests, forest livestock raising, and home gardens. Further work is continuing to build this knowledge base and apply it in efforts to further understand mountain watershed ecosystems and suggest improved management approaches. Expanded ICRAF collaboration is under a new global-level research project on local environmental knowledge (LEK), and the RFD has approved a similar line of research by its Forest Research Office.

(2) Participatory Monitoring

While watershed concerns and tensions are generally rising, local downstream feelings are still largely at the level of concern, apprehension or fear. Moreover, general priorities of these concerns are first with chemical pollution, followed by post-rainy season stream flow and heavy sedimentation of downstream water resources and irrigation infrastructure. One striking feature of most debates and confrontations has been the absence of any systematic efforts to use empirical data to help characterize and assess impacts of changing land use practices and patterns on key watershed functions. While there is a modest body of research on soil erosion and some hydrological properties of particular land uses, the net impact of the types of complex mosaic land use patterns found in most areas has generally remained unaddressed. Moreover, pollution from toxic agricultural chemicals is particularly difficult given their invisibility, the range of chemicals used, and the complexity and cost of methods to directly measure their presence at the often very low concentrations at which they may be chemically active.

Thus, during 1998-99 ASB-Thailand began exploring use of biological indicators of water quality that could be used by trained villagers to measure water quality in a manner that would be credible beyond their own local area or ethnic group. Much preliminary work on aquatic insect indicators was already being conducted by researchers and the Green World Foundation, and other promising indicators included macroalgae, diatoms, riparian plants and animals, etc. Under studies led by Dr. Pornchai Preechapanya (RFD) and Dr. Yuwadee Peerapornpisal (CMU Faculty of Science), use of aquatic insects, macroalgae and diatoms as biological indicators of water quality were tested in streams at selected points in Mae Chaem to determine their reliability under local conditions and the feasibility of their use by trained local villagers. While the reliability of all three types of indicators were confirmed, aquatic insects were found to be the most feasible for use by local villagers. Results on macroalgae and diatoms were presented internationally[33], and a simplified handbook was developed for aquatic insect indicators.[34]

In order to more fully test use of the aquatic insect method under local conditions, trials were conducted at 3 villages of different ethnic groups in each of 2 sub-catchments. Locally selected individuals were trained to monitor rainfall, stream flow, water turbidity, as well as water quality using aquatic insect indicators. Although tests confirmed feasibility of the methods, it also became clear that individual or village-level monitoring would probably not be sustainable. More effective local monitoring systems would need clear endorsement and active support by local multi-village institutions within a sub-catchment. The potential utility of the approach was demonstrated at one site where lowland Thai and Hmong villagers confirmed pollution from agricultural chemicals and located the source of the problem. In this case, it was from chemical use in lowland paddies, rather than initially suspected intensive vegetable fields of the Hmong.

Meanwhile, the Green World Foundation published a series of commercially available Thai language handbooks that include professionally published separate volumes for stream investigators, investigator leaders, and indicator methods for fish, riparian animals, and small freshwater aquatic animals.[35] A kit is available for about Bt 300 that includes all volumes and associated materials, which are now being used in projects, schools and youth nature camps.

2. Information Support Systems for Managing Agroforestry Landscapes

Research findings summarized in this paper indicate a range of impacts and trade-offs among mountain agroforestry landscapes associated with various types of local conditions. As visions and local conditions continue to change, and management responsibility shifts to local institutions, a need arises for continuous feedback on impacts of actual agroforestry mosaic landscape patterns that can be used in continuing collaborative negotiations among institutions responsible for natural resource and development at both local and higher levels of society.

Thus, ASB-Thailand is building on our research results in a current set of policy and action-oriented pilot activities that seek to improve science-based methods for continuously obtaining and integrating relevant information into a system that helps meet both local and national needs. Figure 5 diagrams the overall framework of this approach, which has also elicited interest from neighboring countries during presentations in the context of both MMSEA[36] and the Greater Mekong Sub-region (GMS).[37] Work during 2001 focused on pilot tests in four sub-watersheds of Mae Chaem, where we are building on our previous GIS and monitoring work in collaboration with leaders of local watershed management networks and TAO.

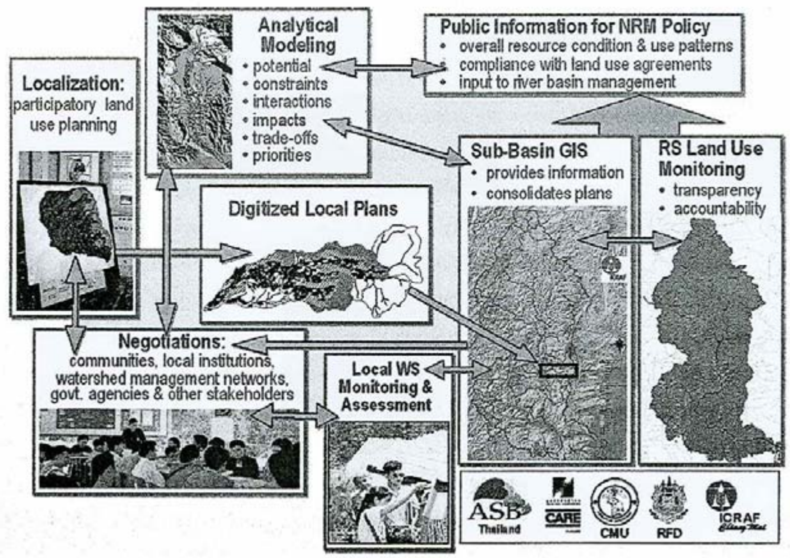


Figure 5. Pilot information support system for agroforestry landscape management.

Major emphasis of the system is on information useful in planning, managing and monitoring natural resource use at various relevant levels. Local information for this system comes from two types of sources: 1) pilot project efforts by our partner institutions to implement locally-negotiated land use zoning using participatory land use planning methods; 2) expansion of community-based monitoring and management activities. Major components of broader scale and higher level information are available in our project GIS, which we continue to supplement through additional remote sensing analysis, as well as other data acquisition methods and secondary sources. While some types of information can be used directly by stakeholders, we also seek to assist interpretations through analyses based on analytical modeling.

Overall focus is on information useful in meeting three types of stakeholder needs:

- Local needs for information useful in land use planning, monitoring and management, which are being identified and refined jointly with local leaders, as well as through monthly field seminars and consultation with key stakeholders and our local development project partners. Monitoring provides dynamic data on the 'bottom line' quantity and quality of watershed services from locally managed landscapes, which should be helpful in identifying local successes and problems, and in managing tensions and conflict between upstream and downstream communities at various scales.

- Needs for improved policy-relevant information available to various levels of the policy making process. For example, local land use plans are being aggregated to demonstrate to resource management agencies the types of patterns and impacts on broader natural resource landscapes that are likely to result from localized zoning. If community forestry legislation is passed soon, we also hope to test use of these zoning arrangements as a basis for establishing official land use agreements in protected watershed areas.
- Needs for public access to information on the status and management of natural resources at various levels. In order to help assure transparency and accountability of localized land use zoning, we are testing use of remote sensing to monitor actual land use against locally formulated plans. This should be public information, along with overall status data.

Since the devastating floods and landslides during mid-2001 in several areas of northern Thailand, the Ministry of Agriculture and Cooperatives and various other agencies and organizations have been discussing approaches for strengthening local capacities to minimize the occurrence and impact of such events. We are now working to integrate these concerns into our pilot information support systems. We also understand that the Thailand Research Fund has recently approved a line of support for activities to develop information systems for local governments. These trends indicate that there is interest in and potential for expansion of approaches such as we are currently testing in Mae Chaem, and we are seeking ways in which our efforts can provide prototype experience for these larger policy formulation and development program activities.

Conclusion

Agroforestry approaches most relevant to immediate concerns in mountain watershed areas of northern Thailand increasingly focus on management of agroforestry landscapes. Since there is quite wide variation both in the profitability of practices associated with agricultural components, and in the degree to which they 'destroy' forests or environmental services, objectives of policies seeking to constrain the range of land use allowed in a particular area need to be clearly stated before an appropriate range of land use practices can be identified. Absence of large stocks of commercial timber, for example, does not necessarily mean that plant biodiversity, methane uptake, or watershed service functions are also absent. Trade-offs between local profitability and environmental services need to be made in a socially acceptable manner, based on realistic assessments rather than wishful thinking.

Moreover, the overall impacts of actual mosaic patterns of agricultural and forestry components in an agroforestry landscape will also depend on the relative balance among components, and their configuration in space and time. For example:

- Relatively large permanent forest components may be able to help mitigate some negative environmental impacts of intensive agriculture, and provide lower-value forest products that can be strategically important seasonally or during crop failures, but their impact on watershed services can be greatly increased or decreased by their position in the landscape.
- Relatively modest profitability of upland rice may be increased (and total area possibly decreased) by longer forest fallows that increase crop productivity and carbon stocks without agricultural chemicals, but watershed impacts will again be strongly influenced by both the area and positioning of forest, fallows and paddies in the landscape.
- Where soil erosion is an important downstream environmental concern, boundary plantings around small upland fields, forest in gullies and along streams, and paddies downslope from upland fields may be at least as effective as contour strip plantings that have been promoted for decades with relatively little success.
- While expanded paddy production can reduce areas required for upland rice, thereby allowing an increase in permanent forest area, their seasonal water use and methane generation are trade-offs, and their ability to 'filter' sediment from streams and upslope open fields will depend on opportunities for water to bypass them through canals or streams.
- Although landscape mosaic patterns may have plant species richness that can approach the level of natural forest, integrity of various plant and animal species may depend on the 'patch size' of different types of component land uses, and the degree to which neighboring patches serve as barriers or corridors.

Given the dynamics of these relationships and their sensitivity to local conditions, there appears to be a need to monitor actual performance of landscape mosaics against natural resource management objectives for a particular area. Standards for monitoring and assessing performance may need to be based on agreements related to land use zoning, patterns and quality of stream flow, location and condition of forest patches, location of settlement and infrastructure, etc. Moreover, the negotiation, planning, monitoring and enforcement of agreements on issues such as these appear to fall within the expanded mandates of local governance institutions, in cooperation with local organizations and government agencies. These processes will require a continuous flow of information as conditions and visions change.

Thus, ASB-Thailand is seeking to adapt some of our scientific research tools to help strengthen local efforts in participatory land use management in mountain watershed areas, aimed at more secure, transparent and accountable land use arrangements, as well as improved common understanding and reduced tension and conflict among upstream and downstream interests.

Reference

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[4] The Alternatives to Slash-and-Burn (ASB) program is a global system-wide initiative of the Consultative Group for International Agricultural Research (CGIAR), implemented through global and national consortia of research institutes, NGOs, and national research, development and extension institutions.

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[22] International price profitability (or 'social' or 'economic' profitability) values use international market prices for inputs or products actually or potentially tradeable in such markets. Calculations assume a 5% interest rate and 35 THB/US$ exchange rate. Returns to farmer labor and land are in Baht person-day^{-1}, while returns to land are in Baht ha^{-1} and use a 40 Baht person-day^{-1} wage rate for labor.

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