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Sustainable Agro-resources Management in the Mountainous Region of Mainland Southeast Asia

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Sustainable Agro-resources Management in the Mountainous Region of Mainland Southeast Asia

Preface

KONO Yasuyuki* and A. Terry RAMBO**

In recent years sustainable rural development has become a primary objective of the governments of all Southeast Asian countries. In the case of agriculture, which is still the main source of livelihood for most people in the region, a farming system is ecologically sustainable when the rate at which resources are used in production does not exceed the rate at which they are regenerated in the farmers' fields. Sustainability, therefore, is determined by the demands of the production system and the inherent capability of the natural environment to meet these demands.

The natural environment of the mountainous region of mainland Southeast Asia represents an especially severe challenge for sustainable development because of its relatively limited capability to support agricultural production. Much of the land is only marginally suitable for agriculture. Traditional subsistence-oriented farming systems tended to be well-adapted to these marginal conditions and were sustainable as long as human needs remained relatively small. However, systems of agricultural production are changing and the load that they place on agro-resources is in most cases increasing. This change is occurring as the result of both internal factors, such as population growth and the declining land-population ratio, and external factors including greater integration into the global economy and enforcement of government policies regulating use of land and natural resources. Farmers trying to adjust their mode of production to these new circumstances must take into account various considerations including their need for higher economic returns, their desire to maintain cultural and social traditions, and the necessity of protecting the local environment. However, the smaller capacity of the natural environment of the mountainous region to support agricultural production limits their freedom of choice and makes achievement of sustainability more difficult.

The papers in this special issue highlight some of the critical problems of agro-resources management in the mountainous region of Mainland Southeast Asia including Vietnam, Laos and Thailand (Fig. 1). The region consists of high mountains with elevations

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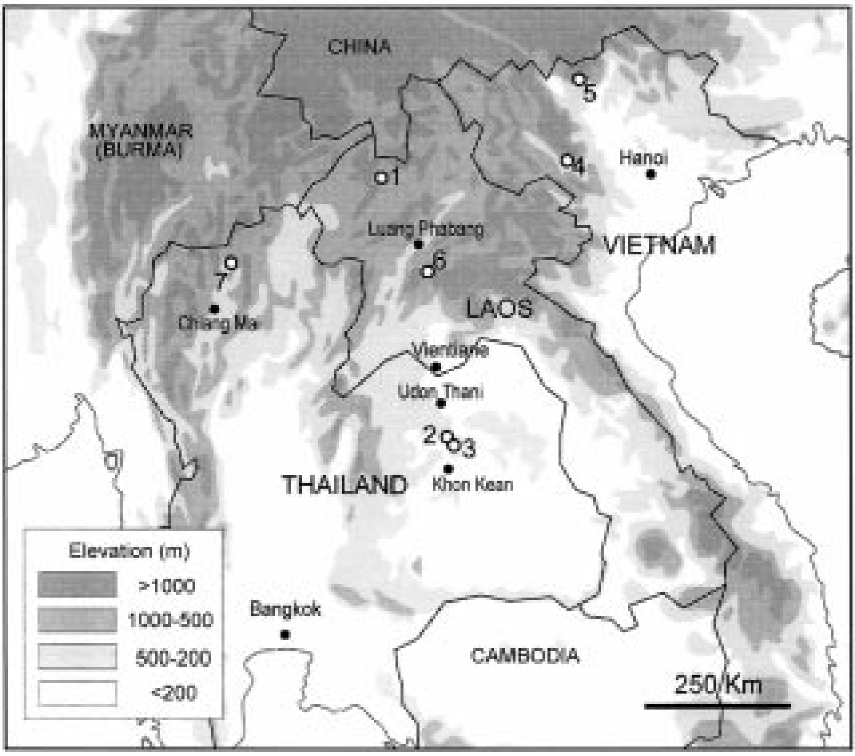

Fig. 1　Location of the Study Sites

1 : Yamada *et al.*　2 : Vityakon *et al.*　3 : Trelo-ges *et al.*　4 : Tran Duc Vien *et al.*
5 : Sakurai *et al.*　6 : Watanabe *et al.*　7 : Ongprasert and Prinz

of more than 3,000 meters above mean sea level, narrow valleys, broad intermountain basins, and large plateaus. Many different minority ethnic groups inhabit this region. They have traditionally practiced shifting cultivation on slopelands as well as lowland paddy cultivation. They have evolved their own sophisticated indigenous knowledge of agriculture and nature which has permitted their survival in an environment which places severe constraints on their agricultural activities. Despite intensive development efforts by national governments, augmented by recent inflows of overseas development assistance funding, the mountainous region remains economically and socially marginal as a result of its difficult natural conditions and distinctive ethnic composition.

In the on-going process of national integration and economic development in the mountainous region, harmonization of agricultural production with environmental conservation is a pressing issue. Growing population pressure and increased involvement in the market system are placing natural resources, especially land and forests, under ever greater pressures. Existing forms of subsistence-oriented agriculture can no longer meet people's needs in a sustainable manner. Ensuring food security is an ever more pressing problem. Policies designed to protect resources may have negative impacts on the food production activity of upland peoples but allowing continued free access to resources can result in irreversible environmental deterioration. Intensification of commercially-oriented agriculture on suitable lands may offer one solution to this development dilemma. Implementing such a development strategy requires clear identification of the potentialities of sloping lands to sustain intensified commercially-oriented agriculture.

In order to explore the possibilities of implementing this strategy we organized an "International Workshop on the Development of Sloping Land Agriculture in Mainland Southeast Asia" that was held at Chiang Mai, Thailand, in March 2002. Nearly 50 scholars from Vietnam, Laos, Thailand, the United States and Japan took part. The aim of this workshop was to reexamine sloping land agriculture in Mainland Southeast Asia based on reports of field studies in Laos, Thailand, and Vietnam. This special issue includes several revised papers from this workshop. In addition we later invited two Thai scholars to contribute papers describing some of the sustainability problems that have occurred as a result of intensification of commercially-oriented agriculture in the Khorat Plateau in Northeastern Thailand where this process has advanced further than in other parts of the mountainous region.

Spatially, the papers in this issue cover Northern Vietnam, Northern Laos, Northern Thailand and Northeastern Thailand. Each area has its own natural environment, ethnic composition, and degree of intrusion of the market economy, and each has been subject to different development policies. Consequently they display wide variation in the types of problems which farmers are facing and the character of their responses to them. Farming systems described in the papers include shifting cultivation as well as wet rice farming, cultivation of dryland cash crops, and agroforestry. Livelihood strategies include subsistence production of food, commercially-oriented growing of cash crops, collection of forest products, and wage labor. Although no purely subsistence farming system is included among the case studies, subsistence-oriented production remains an important aspect of farmer livelihood strategies in all of the cases, even in Northeastern Thailand where integration into the market economy has been underway for more than half a century. We expect that by taking this diversity into account we will deepen our understanding of agro-resources management in the mountainous region of Southeast Asia.

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Use of Natural Biological Resources and Their Roles in Household Food Security in Northwest Laos

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Abstract

The present study focuses on agriculture-forestry-based livelihood systems of Northwestern Lao people through village studies, including semi-structured group interviews, questionnaire survey, participatory observation and wealth ranking in Luang Namtha province. The study also examined the use of natural biological resources and identified their roles in household economy. The study revealed that lowland, hillside and mountain villages have different sets of farming practices including lowland paddy and shifting cultivations and natural biological resources use under the given agro-ecological setting, and natural biological resources play a crucial role in household food security in terms of providing an important source of cash income, particularly for poor people. Multiple functions of forest resources including bio-diversity conservation, fallow for coming cultivation and production of non-timber forest products should be further examined in order to guide development toward environmental conservation, food security and poverty alleviation.

Keywords: agriculture-forestry-based livelihood, biological resources, food security, non-timber forest product, Northwest Laos, shifting cultivation, wealth ranking

I Introduction

Land locked Lao PDR (hereafter Laos), located in Mainland Southeast Asia, is a mountainous country with 70 percent of its land area located at elevations over 500 m above sea level. Forest coverage in Laos was estimated to be greater than 50 percent of land area in 1995, compared to its neighboring countries the natural environment in Laos is relativity rich [FAO 1997]. The total population of 5.2 million people (2000) consists of more than 40 ethnic groups, of which Lao Lum (Lowland Lao), the dominant ethnic Lao and related groups, con-

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stitutes about 60 percent. The average population density is 22 persons/km^2, the lowest of all Southeast Asian nations.

People in Laos have been traditionally engaged in subsistence farming, combining low-land rice cultivation in the plains with shifting cultivation of upland rice on slope lands. In addition to the production of staple foods, farmers have small vegetable gardens and raise livestock to meet their daily needs. Their farming is generally characterized as low input and extensive use of land. It is also relatively vulnerable to pests and disease, as well as to the changes in natural environment such as adversities of climate.

Agricultural statistics [Lao PDR, MAF 1996; 1998; Lao PDR, MEPFSSC 1990; 1991; 1992; 1994; 1996; 1997; 1999] show that the national average of the annual per-capita rice supply (calculated by deducting 60 kg/ha of seed for the next year's production and 13 percent for post-harvest loss from production) was 320 kg/person. Production varies from year to year and from region to region, however (Fig. 1). In the northern region, where mountainous areas are more dominant than in other regions, production fluctuates yearly between 227 and 313 kg. This is much lower than the national average rice consumption of 255 to 390 kg/year/person. This indicates that the mountainous areas in the northern region are most prone to rice shortage in the country.

Rural people in these areas have adopted practical means to cope with rice deficiency. Several researchers already pointed out that natural biological resources play quite significant roles in household food security [Falconer *et al.* 1989; de Beer and Mcdermott 1989; Broekhoven 1996].

Natural biological resources, which are defined as all the biological materials that may be extracted from natural ecosystems and utilized within the household, marketed, or that have social, cultural or religious significance, play an indispensable role in diversifying daily

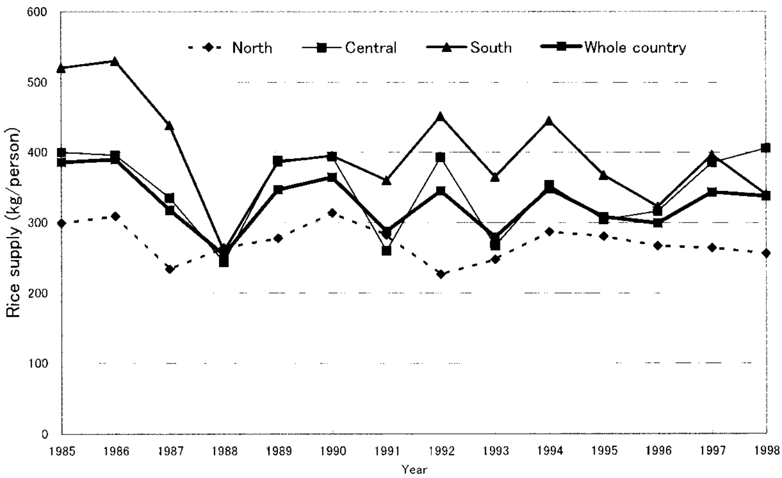


Fig. 1 Year-to-year Fluctuation of Rice Supply in Laos

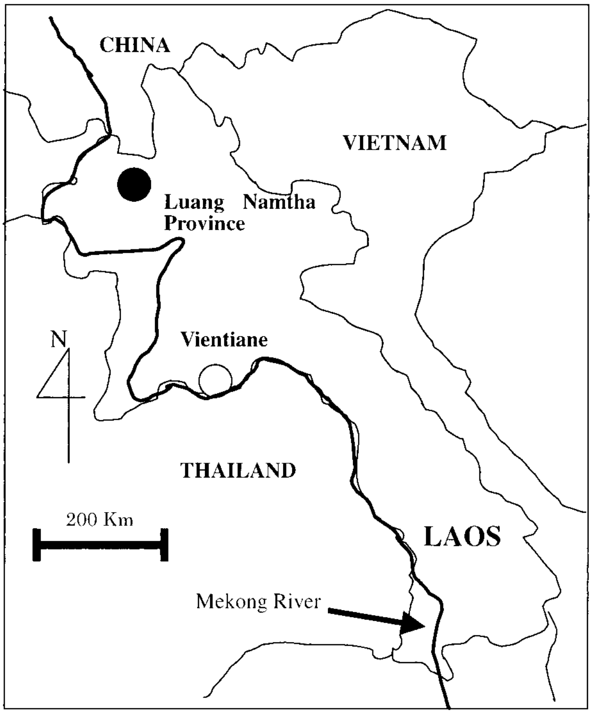


Fig. 2　Map of Study Area

diet of local people. This is a meaningful contribution to their food security because, though household access to staple food items is an important part of household food-security, it is also important to consider other food items that comprise households' daily diet. For example, Danes [1998] noted that despite the fact that farmers in Laos give high priority to achieving self-sufficiency in rice production, they also place considerable importance on collecting other wild food items like vegetables and meats, which supply vitamins, minerals and protein in their daily diet.

Another contribution of natural biological resources to household food security is as a source of cash income. Local people sell natural biological resources and use the cash to buy rice to supplement their own production and achieve food security. But the significance of this role may differ by the environmental setting of the settlement and the economic conditions of the household.

Even in Laos, environmental degradation has become a prominent problem in the last decade due to increased population pressure and expansion of agricultural land induced by changes in the economic system and spread of market economy [Chape 1996]. Consequently, the Lao government has adopted policies to curb environmental degradation. These include measures to stabilize shifting cultivation, to designate protected areas, and to allocate agricultural and forest land to households. These policies aim to improve the national economy and protect the natural environment by intensifying agricultural production and conserving forest resources. Little consideration has been given to the rural population's use of natural biological resources. This indicates that the government's understanding of rural livelihoods is limited to farming activities, and lacks the scope to include a wide range of non-farm activities, including the utilization of natural biological resources.

The present study, therefore, aims at examining the use of natural biological resources and identifying their roles in household economy, particularly from the viewpoint of contribution to food security at the household level. A better understanding of household use of natural biological resources may contribute to establishing sustainable livelihood systems based on an agriculture-forestry complex in the mountainous regions of Laos.

We selected Luang Namtha province, the northwestern part of Laos as the study area (Fig. 2). This part of the country still has a relatively rich natural environment, and natural biological resources are expected to play a significant role in people's livelihood. Moreover, it borders with China, which is the main importer of natural biological resources. This also suggests that cross-border trade in natural biological resources should be observed widely.

II Field Survey

The field survey, conducted during the period between May 2000 and September 2001, consisted of village studies, market surveys and collection of data from related government agencies. This was done by some of the authors in collaboration with staff of the Provincial Agriculture and Forestry Office (PAFO). The language used for the field survey was mainly Lao, and we asked village headmen to serve as translators between Lao and indigenous languages, when necessary.

The village studies consisted of 1) semi-structured group interviews, 2) questionnaire surveys, 3) participatory observation, and 4) wealth-ranking analysis.

Semi-structured group interviews of village leaders were carried out in 13 villages in May and June, 2000. This aimed at collecting preliminary information on history of settlement, socio-economic conditions, agriculture, natural biological resources use, social organization, and market access. The 6 study villages were then chosen for the following survey.

Questionnaire surveys of all households were carried out in the study villages during the period from July to November, 2000, and were supplemented by a second survey during the period from July to September, 2001. The questions included cash income, farming activities, collection and use of natural biological resources, rice balance and measures for achieving food security. The survey was done at the house of each informant. This also provided us with a chance to observe living conditions. We arranged for both the household head and his spouse to attend the interview in order to obtain precise information within a short period of time.

Participatory observation on hunting and gathering of natural biological resources and daily diet was carried out at selected households during the periods from August to November, 2000 and July to September, 2001. This provided information to confirm the results of the questionnaire survey and in-depth information on natural biological resources collection and use.

Wealth-ranking aimed at classifying all households into three economic classes. We asked village leaders to take part in wealth ranking. They judged all households of their village as wealthy, middle or poor household, from the viewpoint of land holdings, ownership of durable consumer goods and other property, rice balance, and family labor supply (see more in details in Jackson and Ingles [1998]).

Market surveys were carried out at the central market of Luang Namtha town twice a month during the period from August 2000 to July, 2001. We prepared a list of goods sold at the market particularly from the viewpoint of whether they are natural or cultivated.

III Study Area

III–1 *Diversity of Livelihood Systems in an Agriculture-forestry Complex*

Luang Namtha province has rich forest resources. The Provincial Agriculture and Forestry Office reported that 59 percent of the province was covered with forest in 1995, of which 12.5 percent was National Bio-diversity Conservation Area, 7.3 percent was Provincial Bio-diversity Conservation Area, and 5.6 percent was District Bio-diversity Conservation Area. The remaining forests are mostly village forest lands which include *pa sanguan* (conservation forest) and *pa pongkan* (protected forest). These forests are mixed deciduous forest and regenerated forest after shifting cultivation.

This province is home to various ethnic groups. These include the Lao, Tai, Lue of the Tai-Kadai language group, the Khmu and Khabit of the Mon-Khmer language group, the Akha of Sino-Burmese language group, and the Hmong and Yao of Hmong-Mien language group. These ethnic groups are commonly classified into three major groups. Lao Lum (Lowland Lao) are people speaking Tai-Kadai languages, Lao Theung (Midland Lao) belong to the Mon-Khmer language group, and Lao Soung (Highland Lao) belong to the Tibeto-Burman and Hmong-Mien language groups.

The agro-ecological landscape has three zones: lowland, hillside/valley and mountain (Table 1).

The lowland zone occupies the intermountain basin of Luang Namtha, which is an area of flat land mostly covered with paddy fields. We can observe scattered forest along the riverside and settlement, which mostly consists of useful varieties including fruit trees. The major inhabitants are Lao Lum groups, including Black Tai and Tai Lue, who have been engaged in irrigated lowland paddy cultivation since they settled the area.

The hillside/valley zone is located in the areas surrounding the lowland zone. Its topography is a complex of narrow valley and slope land originally covered with evergreen or

Table 1 Agro-ecological Landscape of Agricluture-forestry Conplex in the Study Area

Zone	Altitude (m)	Geographical Features	Agricultural Landscape	Natural Vegetation	Main Tribes
Lowland	560–600	Intermountain basin with gentle slope	Irrigated and rainfed paddy field	Grass land	Black Tai
		Meandering rivers with many tributaries	Shifting cultivation with 1 to 2 years fallow	Evergreen forest (cemetery forest)	Tai Lue
		Marsh/ponds	Vegetable garden along river/ tributary garden of bamboo and banana	Secondary evergreen forest Mixed deciduos forest	Tai Nguan
		Near markets (30 minutes to 1 hour by walk)	Plantation of mulberry and teak Fish pond	Bamboo stands	
Hillside/valley	550–700	Gentle/moderate slopeland	Shifting cultivation with 3 to 5 years fallow	Secondary evergreen forest	Khmu Rok
		Stream/river with many tributaries	Paddy field and vegetable garden in valley	*imperata* grass	Khmu Nguan
		Narrow valley	Plantation of teak, rubber, *nyaka*, bamboo and banana	Mixed deciduous forest	Khabit
		Moderate distance to markets (One hour by bicycle)		Bamboo stands Primary evergreen forest	Lanten White Hmong
Mountain	700–1,500	Gentle/steep slopeland	Shifting cultivation with 6 to 20 years fallow	Primary evergreen forest	Akha
		Mountain torrents	Upland fields of maize, cotton, vegetables, opium and banana	Mosaic of secondary forest	White Hmong
		Very far to markets (3–8 hours by walk)		*imperata* grass	Yao Sila

mixed deciduous forests. Valley is reclaimed as fields and vegetable gardens, and slope land is partly occupied by shifting cultivation and tree plantations including teak and rubber. Major inhabitants are Lao Theung, represented by a majority of Khmu. They were formerly shifting cultivators, but introduced lowland paddy cultivation several decades ago.

The mountain zone occupies the rest of the area. Most of mountain slope is, even now, covered with primary evergreen forest, which is rich in non-timber forest products. Major inhabitants are Lao Sung including Yao, Hmong and Akha, and the predominant mode of agriculture is shifting cultivation.

III–2 *The Study Villages*

We selected six villages, two from each agro-ecological zone, for intensive survey.

The two lowland villages are Black Tai. The total population is 634 people, and the number of households is 98. Of this number, 85 are farmer households, in the sense that their major income source is agriculture. Others are engaged in trading, wage labor, or getting pension or remittance. Both villages were settled more than 100 years ago. They have good access to the market, and are located 30 minutes to one hour by foot from these villages to the provincial town.

The two hillside villages have, in total, 778 persons and 138 households, of which 97 are farmer household. The residents are Khabit and Khmu who settled down the area more than 100 years ago and 25 years ago, respectively. They can access the market in approximately one hour by bicycle.

The two mountain villages have, in total, 854 persons and 119 households, of which 114 are farmer households. They are Akha villages, one of which settled down at the present location 62 years ago, and the other 9 years ago. It takes eight and three hours to walk to the market from the old and new village, respectively.

IV Farmer Household Economy

IV–1 *Farming Activities*

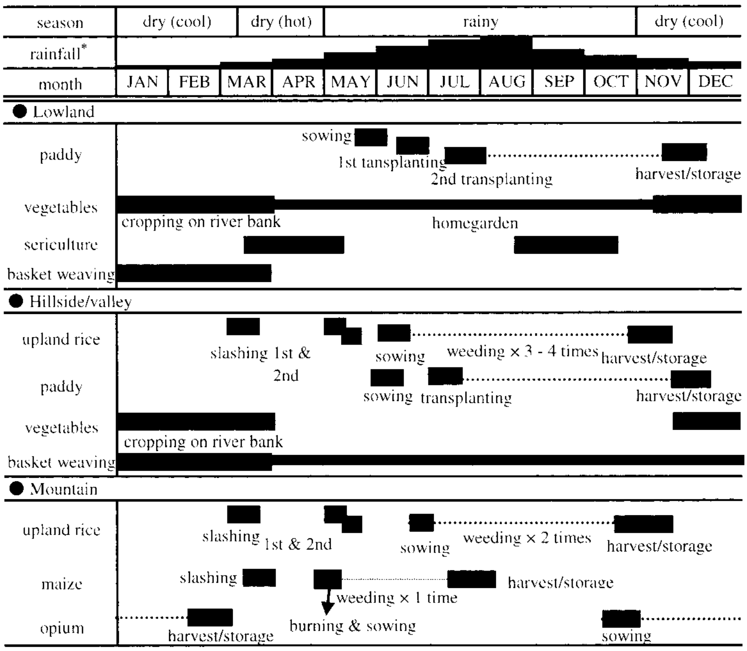
The major mode of food production is lowland paddy cultivation in the lowland villages, shifting cultivation of upland rice in the mountain villages, and a mixture of the two in the hillside villages. We can see this tendency at the selected villages (Table 2; Fig. 3).

In the lowland villages, almost all farmer households are engaged in lowland paddy cultivation. Their average farm size is nearly 1 ha and a household produces, on average, 2 tons of paddy in a normal year. Rice production is supplemented by small-scale shifting cultivation that about the half farmer households are engaged in.

The lowland villages grow abundant vegetable crops, and are active in sericulture, raising of water buffalo and cattle, and fish culture. Dry season vegetables and spices, silk, cattle and other animals are important sources of cash income. In comparison to the hillside

Table 2 Farming Activities in the Study Villages

Zone	Lowland	Hillside/Valley	Mountain
Farming structure (% of household)			
Lowland paddy	41	4	0
Lowland paddy + shifting cultivation	54	25	3
Shifting cultivation	5	71	97
Lowland paddy cultivation			
Average farm size (ha)	0.92	0.46	0.78
Average rice yield (t/ha)	2.2	1.3	1.7
Shifting cultivation			
Fallow period (year)	1 to 2	3 to 5	6 to 20
Average number of livestock (head/household)			
Water buffalo	1.0	0.5	0.8
Cattle	2.0	0.4	0.4
Pig	1.8	2.9	2.7
Goat	no	0.1	0.6
Horse	no	no	0.1
Duck	7.6	1.3	0.2
Chicken	9.5	4.9	11.7
Turkey	0.6	no	no
Dog	no	no	1.2
Holding of machinery (% of household)			
Tractor	4	1	no
Power tiller	49	7	no
Motorbike	3	1	no
Bicycle	88	64	no
Rice mill	7	4	2



*Shows the general trend of rainfall

Fig. 3 Major Cropping Calendar at the Study Villages and mountain villages, they also have a greater number of agricultural and transportation machinery, such as power tillers and tractors. These reflect year-round access to water sources and good road conditions.

In the hillside villages, almost all farmer households are engaged in shifting cultivation, with one fourth also cultivating lowland paddy. The fallow period of shifting cultivation is three to five years, which is much shorter than in the mountain villages. The average farm size of lowland paddy field is about half of that of the lowland villages. These indicate less advantageous land conditions of the hillside villages, when compared to the mountain and lowland villages.

Among the three agro-ecological zones, farming systems in the hillside villages may be the most diverse because they have both lowland and upland environments. They grow vegetables in fields along streams in the dry season, as it is done in the lowland villages, and by mixed-cropping with upland rice, as in the mountain villages. But both are limited due to smaller farm size and less fertile soil.

In the mountain villages, rice production depends on shifting cultivation. The fallow period of shifting cultivation is as long as 6 to 20 years, reflecting sufficient available land resources, and results in high land and labor productivity.

They are also rich in non-rice upland farming owing to abundant and fertile land. They grow maize and cotton in separate fields. Pumpkin, cassava, chili, maize, cucumber and ginger are inter-cropped with upland rice. They grow banana after the harvest of upland rice. Animal husbandry such as pigs, goats and poultry is popular. These products are mostly consumed at home due to difficult access to the market.

IV–2 *Cash Income* [1)]

Cash income of all farmer households of the study villages in the year 1999/2000 was obtained from the questionnaire survey. The average cash income was the highest in the lowland villages, US$43/person/year, followed by the mountain villages, US$38/person/year, and the hillside villages, US$30/person/year. Villagers reported that the year of 1999/2000 was a normal year in terms of natural disaster and economy. Thus, this tendency should be general in recent years.

The wealth ranking exercise classified all households into wealthy, middle and poor classes. The results of the questionnaire survey and wealth ranking coincided well, and significant differences in cash income can be observed between economic classes (Table 3). The number of households classified as wealthy, middle and poor class is nearly one third each in the lowland and mountain villages, while the wealthy class is 11 percent and the middle and poor classes are 44 percent each in the hillside villages. The average per capita

1) In this paper, the amount of cash income is estimated from sale and barter of agricultural products and natural biological resources. One US dollar is equal to 8,000 kip, and one kilogram of unhusked rice is estimated at 1,000 kip. The amount of self-consumption is not included in cash income.

Table 3 Cash Income and Income Sources

Wealth Rank	Number of Household	Total Income (US$/person)*	Source of Income(%)			
			Farm Products	Livestock	Wage Labor	Natural Biological Resources
Lowland						
wealthy	30	65.2±13.5	49	27	10	14
middle	21	33.0± 6.6	36	23	27	14
poor	24	24.1± 3.7	22	19	25	34
Hillside/valley						
wealthy	11	40.6±12.0	26	47	18	11
middle	43	31.0± 4.0	13	28	33	26
poor	43	27.1± 2.3	2	10	55	33
Mountain						
wealthy	43	57.3± 4.5	3	48	2	47
middle	39	28.0± 2.5	2	34	4	61
poor	32	24.4± 2.0	2	30	7	61

* Shows the average and standard deviation. People less than 16 years old and more than 64 years old are equivalent to 0.5 person in estimation.

annual cash income of the middle and poor classes are almost the same in all villages, US $30 and US$25 respectively, while that of the wealthy class is higher in the lowland and mountain villages at about US$60, than the US$40 in hillside villages. Thus, compared to the lowland and mountain villages, the hillside villages are economically more homogeneous due to lack of wealthy households.

The lowland and hillside villages show a similar pattern with regard to the composition of income sources. About 75 percent of cash income of the wealthy class comes from farm products such as rice, vegetables, silk and bananas, and livestock such as pigs, water buffalo, cattle and poultry, while more than half of the cash income of the poor class is derived from wage labor such as construction work and agricultural labor, and natural biological resources. The poor class in the hillside villages is heavily dependent on income from wage labor, particularly construction work. On the other hand, in the mountain villages, income sources do not differ by economic class, and more than 90 percent of cash income of all classes is derived from sale of livestock of pigs and cattle, and natural biological resources.

V Natural Biological Resources Use

V–1 *Hunting and Gathering Activities*

Evenson [1991] reported that he found more than 250 varieties of fruits and vegetables in Lao markets, of which 140 varieties are natural biological resources. We also surveyed Luang Namtha Central Market and found 106 varieties of fruits and vegetables, of which 37 were wild. This indicates that natural biological resources are widely used in the daily life of the rural population.

Major hunting and gathering activities of natural biological resources observed at the

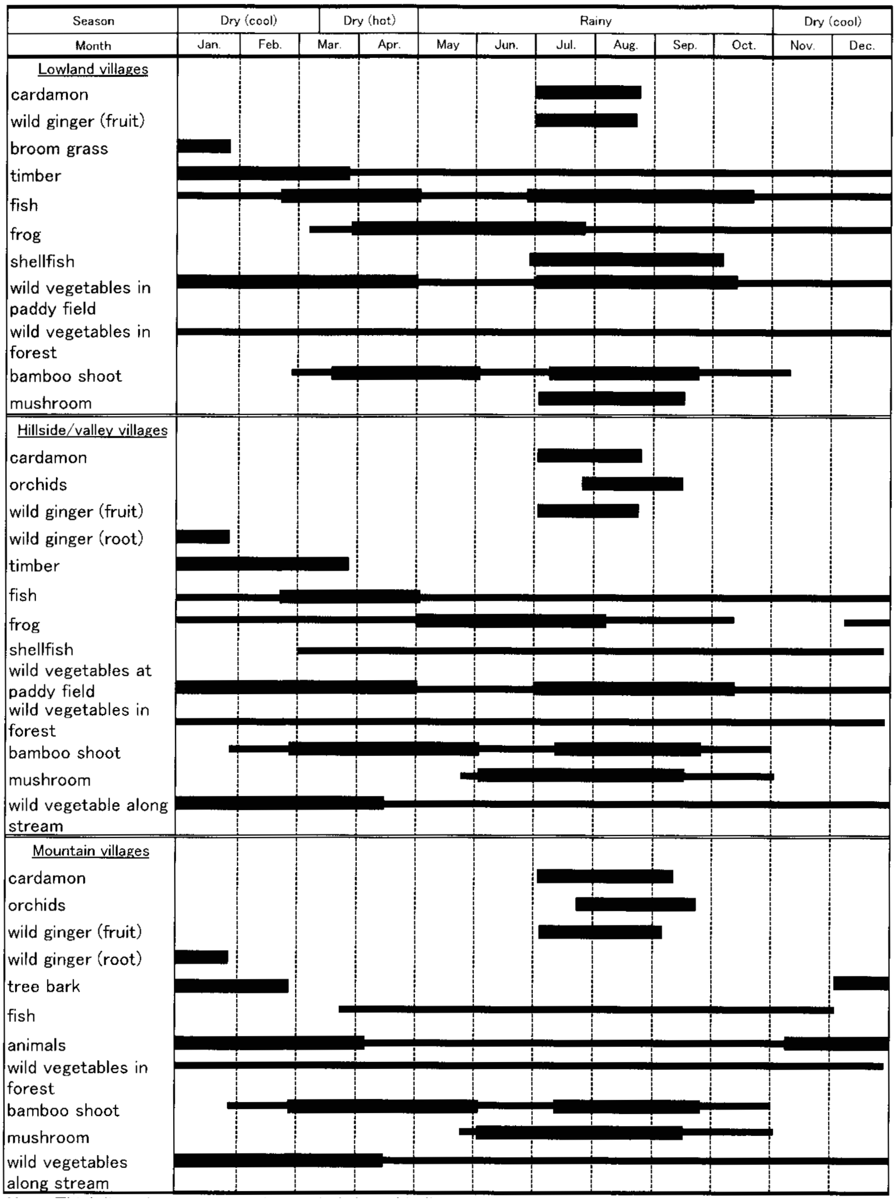


Fig. 4　Major Hunting and Gathering Activities

Note: Thick line shows more active period than thin line.

study villages are summarized in Fig. 4.

In the lowland villages, paddy fields and their surrounding area provide various kinds of flora and fauna. Weeds in paddy field such as *phak ween (Marsilea quadrifolia)* and *phak nok (Cantalla asiatica)* are important vegetables for local people year-round. People also catch aquatic animals including fish, frogs, shellfish, crabs and insects by means of rod, net and various sizes of trap. They catch fish in the paddy fields, particularly in the latter half of the rainy season, and in the river in the dry season when the water level is low. People also collect bamboo shoots and banana flowers in nearby hilly areas, and fern (*Pteridium aquilinum, Lygodium conforme* and *Gleichenia linearis*) along streams.

In the hillside villages, people collect rattan, banana flowers and bamboo shoots in surrounding degraded forest. Rattan handicrafts are quite popular. Mushrooms and fern can be found on fallow land after shifting cultivation at the beginning of the rainy season. Hunting of small animals such as rats, deer and birds in shifting cultivation fields and surrounding forests is also practiced by means of various types of trap. For example, a *heu* is a trap set on the ground to catch small animals. A *long* is a trap set on trees to catch birds, and a *kup* is a baited cage to catch birds. They also walk into deep forest to collect cardamom, orchids and wild ginger.

In the mountain villages, various types of forest including primary forest, secondary forest and bush after shifting cultivation accessible to the people. These forests provide a wide range of non-timber forest products. In addition to cardamom, orchids and wild ginger, wild fruits such as *mak ngeo* (*Xerospermum laoticum*), *mak wa* (*Eugenia* sp.) and *mak ko* (*Diospyios hayatae*), wild insect such as bee and moth larva, and honey are collected in the primary forest. Hunting of wild animals such as bear, deer, squirrels, monkeys and wild boar is also practiced, particularly in the dry season. Hunters use homemade matchlock guns for hunting.

V–2 *Sale of Natural Biological Resources*

Local people sell natural biological resources directly in local markets and also through middlemen. Some precious non-timber forest products are traded to Chinese middlemen. These are mostly materials for Chinese medicinals and incense, which are exported to China, Taiwan, Korea, Japan and Thailand.

The results of the questionnaire survey on the sale of natural biological resources by all farmer households of the study villages are summarized in Table 4.

The average amount sold is the highest in the mountain villages, US$85/year/household, followed by the hillside villages at US$41/year/household, and lowland villages at US $23 /year/household. These amounts represent 53 percent, 27 percent and 18 percent of total household cash income, respectively. The composition of natural biological resources also shows a big difference among the villages. Cardamom, orchid and wild animals, which are expensive and for export, are the most important cash sources in the mountain villages. This clearly indicates that people in the mountain villages enjoy rich forest resources. More

Table 4 Sale of Natural Biological Resources

Kinds of Natural Biologial Resources			Purposes	Place Collected	Sales* (US$/household)		
English Name	Lao Name	Scientific Name			Lowland	Hillside/Valley	Mountain
Export							
cardamon	mak neen	*Amomum ovoideum, Amomum villosum*	medicine	primary forest	0.99	1.65	58.89
orchid	nya bai lai	*Ludisia discolor*	medicine	primary forest	0.00	0.05	7.17
wild ginger	kha	*Alpinia* spp.	medicine	primary forest	0.00	0.00	2.24
tree bark	puak muak	*Debregaesia hypoleuca*	glue	primary forest	0.11	0.82	3.56
rattan fruit	mak wai	*Calamus* spp.	medicine	primary forest	0.08	2.62	1.18
suger palm	mak tao	*Arenga saccharifera, Arenga awesterhoutii*	medicine	primary forest	0.00	0.18	0.00
eagle wood	mai kesana	*Aquilaria crassna*	perfume	primary forest	0.78	0.00	0.00
Sub-total					1.96	5.32	73.04
Local market							
wild pepper	mak keen	*Zanthoxylum rhetsa*	spice	primary forest	0.00	0.00	0.07
not available	sakhan	*Piper* spp.	spice	secondary forest	0.00	0.00	0.00
rattan shoot	nyot wai	*Calamus* spp.	food	fallow forest/ primary forest	0.00	0.49	0.00
bamboo shoot	no mai	*Indosasa sinica,Thyrostachys siamensis, Bambusa tulda, Bambusa spinosa*	food	fallow forest/ primary forest	2.77	7.71	3.15
banana flower	mak pi	*Musa* spp.	food	fallow forest	0.65	2.19	0.00
wild litchi	mak ngeo	*Xerospermum laoticum*	fruit	primary forest	0.00	0.00	0.44
honey	nam pung	not available	food	primary forest	0.00	0.04	0.86
not available	mak ko	*Livistona saribus*	food	primary forest	0.00	0.00	0.28
wild vegetables in forest	phak pa	*Pteridium aquilinum, Lygodium conforme, Piper lilot,Eugenia* spp., *Diplazium esculentum, Oroxylum indicum, Diospyros mollis*	food	fallow forest/ primary forest	0.83	2.81	0.00
wild vegetable in paddy field	phak na	*Marsilea quadrifolia, Cantalla asiatica, Eichornia crassipes, Ipomoea aquatica*	food	paddy/wetland	0.48	0.44	0.00
not available	mak fai	*Clausena lansium, Baccauvea sapida*	fruit	primary forest	0.13	0.25	0.00
not available	mak vai	*Calamus (godefroyi)*	fruit	primary forest	0.00	0.00	0.85
mushrooms	hed	*Agaricus integer, Auricularia* spp.	food	fallow forest/swedden field	0.04	0.03	0.47
fish	pa	*Mastacembelus armatus, M. nemurus, Monotreta* spp. *Puntius brevis, Macrognathus siamensis, Pristolepis fasciata, Oreochromis niloticus, Tilapia niloticus, Tilapia niloticus, Cyprinus carpio, Monotreta* spp. *Leiocassis siamensis*	food	river/paddy/wetland	15.65	1.19	0.00

Table 4—Continued

Kinds of Natural Biologial Resources			Purposes	Place Collected	Sales* (US$/household)		
English Name	Lao Name	Scientific Name			Lowland	Hillside/Valley	Mountain
shellfish	hoi	not known	food	paddy/ wetland	0.55	0.00	0.00
animals	sat pa	*Sus scrofa, Muntiacus muntjak,Tragulus javanicus, Callosciurus* spp. *Gallus gallus, Lophura nycthemera*	food	fallow forest/ primary forest	0.00	0.00	6.12
wood (firewood and timer)	mai	*Sandricum Indicum, Schizostachyum zoilingen, Mansonia gagei, Livistona cochinchinensis, Michelia champala, Thyrostachys siamensis, Dendrocalamus strictus, Schizostachyum zoilingen*	wood	fallow forest/ primary forest	0.04	3.03	0.00
handicraft (baskets and broom grass)	hatakam	*Cephalostachvum virgatum, Calamus* spp., *Thysanolaema maxima*	handicraft	fallow forest/ primary forest	0.20	17.78	0.00
Sub-total					21.34	35.96	12.24
Total					23.30	41.28	85.28

* The average of all households at the study villages in the year 1999/2000.

than 70 percent of the income of the hillside villages comes from handicrafts, rattan fruit and bamboo shoots, which are collected in primary and degraded forests. The lowland villages, with paddy fields and perennial water flow of rivers, earn their major incomes from fish.

VI Household Food Security

VI–1 *Rice Balance*

Farmers measure the sufficiency of their rice production in terms of how many months it can afford home consumption. After the harvest, which is November/December in case of lowland paddy and October/November in case of upland rice, farmers consume the rice they have harvested. If it exhausted before the next harvest, however, farmers face rice shortages and have to look for ways to cope in times of scarcity. The rainy season is the hardest time for them. If they have surplus even at the time of the next harvest, the surplus is stored to carry it over to the next year in case there is a poor harvest in the coming years.

Rice balance in the study villages reflects the situation of rice production of each village (Table 5).

Rice production is most sufficient in the mountain villages where almost two thirds of the farmer households do not face rice shortages and the reminder face shortages of one to three months. In the lowland villages, only two fifths of households are fully sufficient and about two fifths face shortages of one to three months. The reminder face shortages for more than four months. On the other hand, rice production is insufficient in the hillside villages. Production covers consumption for eight months or less for more than half of the households.

Overlaying wealth ranking with rice balance reveals a contrast among the villages. In the lowland villages, the wealthy class has sufficient rice production, while the most part of the middle and poor classes face rice shortage for one to three months and more than four months, respectively. In the hillside villages, the wealthy class has sufficient rice production, as observed in the lowland villages, the middle and poor classes face rice shortage for one to six months and more than four months, respectively. These findings suggest that rice balance is one of the outstanding indicators of the intra-village economic class in these villages, and producing sufficient amount of rice is a symbol of the wealthy class. In the mountain villages, on the other hand, most of the wealthy and middle class households produce suffi-

Table 5 Rice Balance in 1999/2000

(Unit: % of household)

Shortage Period*	Lowland	Hillside/Valley	Mountain
More than 7 months	8	27	0
4 to 6 months	17	39	6
1 to 3 months	36	25	33
Sufficient	39	10	62

* This refers to the period when home consumption can not be born by self-produced rice.

cient amount of rice, and some poor-class households face rice shortage. Considering that the sale of rice is negligible, as shown in Table 3, rice balance is not the determinant factor of the intra-village economic class in the mountain villages.

VI–2 *Contribution of Natural Biological Resources*

There are several ways that people in Laos cope with rice shortage. First, they borrow rice from relatives and neighbors, and return it after the next harvest. Second, they purchase rice or exchange goods for rice at the market or with neighbors. Third, they sometimes beg for rice from neighbors. Fourth, they substitute rice with other crops such as maize and wild tubers (*Dioscorea* spp.).

Table 6 summarizes the methods of supplemental rice acquisition in the study villages.

The total volume of acquired rice is the smallest in the mountain villages, followed by the lowland villages and then the hillside villages, which reflects the differences in rice balance among the study villages (Table 5). The poor class of the hillside villages shows the maximum average volume of 145 kg/person/year, which almost reaches half of their annual consumption.

In the hillside and mountain villages, the major method to acquire supplemental rice is by purchasing it, while borrowing also contributes substantial volume in the lowland villages, particularly for the middle class. This difference may reflect the difference in mode of rice production. In the case of shifting cultivation, the determinant factor of farm size is family labor, resulting in the limitation of surplus production, if any. On the other hand, in case of lowland paddy cultivation, rich farmers try to expand farm size. Paddy field is recognized not only as a tool for production but also as an investment. This creates large-scale farmers who produce sufficient amount of rice to lend.

Table 6 Method of Supplemental Rice Acquisition

Wealth Rank	Supplemental Rice Acquisition[1)] (kg/person/year)				Purchasing Value	
	Total	Borrow	Purchase	Beg	Price[2)] (US$)	% to Total Cash Income
Lowland						
wealthy	0	–	–	–	0.0	–
middle	45	34 (75)	7 (16)	4 (9)	0.9	3
poor	80	30 (38)	49 (61)	1 (1)	6.1	25
Hillside/valley						
wealthy	0	–	–	–	0.0	–
middle	97	16 (16)	78 (81)	3 (3)	9.8	32
poor	145	19 (13)	122 (84)	4 (3)	15.3	56
Mountain						
wealthy	0	–	–	–	0.0	–
middle	25	4 (16)	18 (72)	3 (12)	2.3	8
poor	69	17 (25)	47 (68)	5 (7)	5.9	24

1) Number in parenthesis shows the percentage of proportion of each method.
2) Calculated by the unhusked rice price of US$ 0.125/kg.

The necessary expenditure to purchase the supplemental rice and the contribution of the sale of natural biological resources to the total cash income are 25 percent and 34 percent for the poor class in the lowland villages, 32 percent and 26 percent for the middle class of the hillside villages, 56 percent and 33 percent for the poor class of the hillside villages and 24 percent and 61 percent for the poor class of the mountain villages. These results strongly indicate that natural biological resources are indispensable as a source of cash income to achieve household food security for poor people.

Another important point is the seasonality of cash flow. Rice shortages hit people before the harvesting season. This is when people have to purchase rice. The rainy season, just before the harvesting season, is the high season for the collection of non-timber forest products such as cardamon, orchid and wild ginger, and aquatic animals such as fish, frog and shellfish at paddy field (Fig. 4). The timely sale of these biological resources helps to overcome the rice shortage of poor people who generally do not have savings.

VII　Conclusions

The present study focused agriculture-forestry-based livelihood system of Northwestern Lao people. Lowland, hillside and mountain villages have different farming systems harmonized with their agro-ecological setting. The major modes of agriculture are lowland paddy cultivation, short-fallow shifting cultivation supplemented with lowland paddy cultivation and long-fallow shifting cultivation, respectively. The farming system interacts with forest and water resources of each zone. The mountain zone is covered with deep primary forest, while most of the remaining forest is degraded in the hillside/valley zone. Water resources are rich and diverse in the lowland zone, but limited in the hillside/valley and mountain zones. These are again closely related with natural biological resources use. Major natural biological resources in terms of cash income are aquatic animals and wild vegetables found in rivers and paddy field in the lowland zone, rattan, banana and bamboo collected in degraded forest in the hillside/valley zone and cardamon, orchid and wild ginger collected in deep forest in the mountain zone. We can see multiple functions of the agriculture-forest complex under different settings. This suggests that the local people have detailed environmental knowledge supporting these area-specific uses of biological resources.

Natural biological resources play a crucial role in household food security in terms of not only providing a wide range of food and nutrition, but also providing an important source of cash income and securing year-round acquisition of staple food, particularly for poor people. This finding suggests the necessity of re-considering the role of forest resources in the development strategy of the mountainous areas. Thus, forestland is a treasure house of biological resources and its protection is undoubtedly important, but this does not always mean that people's access to forestland must be prohibited. Forestland is also a growing space of natural biological resources such as non-timber forest products. They are renewable resources. Moreover, regular intervention by human beings may enrich their growth. In addition to bio-diversity conservation for the next generation, the production aspect of forestland should be more emphasized in forest resources evaluation.

It is highly possible that the economic value of natural biological resources in the study area will increase in the future because the degradation of natural environment has accelerated in every country and is causing scarcity of natural biological resources. Laos, particularly the study area, still has comparatively rich resources, which can be a great economic advantage to the area if managed in a sustainable manner. The development strategy of the mountainous areas should be shifted from agriculture-oriented one to the mixture of agriculture and forest use, particularly the mixture of shifting cultivation and productive fallow.

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From Forest to Farmfields: Changes in Land Use in Undulating Terrain of Northeast Thailand at Different Scales during the Past Century

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Abstract

Contemporary land-use change during the past century in Northeast Thailand was analyzed at four socio-ecological scales: region, community, landscape and field plot. The main objectives were to elucidate factors influencing the change and identify effects of the change on the present land conditions. At all scales the land was transformed from forest to cultivated fields by pioneering farmers but such land transformation did not lead to rapid forest loss in the earlier subsistence economy period. Rapid forest loss only occurred after the economy became more commercialized with the expansion of cash crop cultivation in the early 1950s. Land transformation began in the lowland (prime areas for paddy fields) and expanded upward to the uplands. Population growth was the major factor for land-use change in the earlier stage while subsequently the growing commercialization of agriculture was the main factor. Changes in land use have resulted in degradation of land in the upland fields but not in the paddy fields. The upland fields have higher soil erosion and lower soil organic matter pools than the natural forest. The paddy fields, however, do not show indications of being degraded, probably because of their inherent soil properties and their location in the low-lying areas where they receive continuing in-flows of nutrients eroded from higher parts of the landscape. A number of measures to counter the land degradation are suggested including adopting of a more polycultural form of agriculture by integrating trees into agroecosystems at all scales. Such polycultural systems mimic the natural forest ecosystem which is more sustainable ecologically than monocultural systems. In addition, farmers in the Northeast should readopt some degree of subsistence-orientation which would increase the economic and social sustainability of Northeastern agriculture.

Keywords: agroecosystem, forest, land-use change, land degradation, spatial scales, sustainability, twentieth century, Northeast Thailand

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I Introduction

The study of land-use change is the analysis of past human interaction with the land that has brought about effects perceivable in the present. The history of land use of a geographical area within a predetermined time frame is investigated to bring about a clearer understanding of the present state of its land resources. The Northeast region occupies one-third of Thailand's land area (170,000 square kilometers) and is home to one-third of its population (approx. 20 million). Although it is the poorest region economically, it holds potential to be developed due to its vast area and large population. During the last century, however, its land resources, especially forest, soil, and water, have deteriorated. The area covered by forest declined from 90% in the 1930s to less than 14% today while soil degradation due to widely practiced forms of agricultural land use has brought about yield decline and a threat to long-term use of the land.

The objective of this paper is to analyze contemporary land-use change in the Northeast at various spatial scales. This analysis seeks to identify factors influencing the change and describe presently perceivable land conditions. In addition, some opportunities for future development are discussed.

II Methodology and Analytic Framework

In this study, land-use change in the Northeast is analysed at different spatial scales or levels in the agroecosystem hierarchy. Rambo [1991] proposed two parallel hierarchies, one ecological, the other social, for studies of agroecosystems in the Northeast. A somewhat similar approach is employed in this paper. In the ecosystem hierarchy, the systems in ascending order of spatial scale are field plot, landscape, watershed, river basin, continent, and the whole biosphere, while the farm household, village, district, province, nation, continent, and global system represent the ascending levels in the social-political-administrative system hierarchy. This set of parallel system hierarchies is used because there are discrepancies between the scales employed in ecological and social science analysis of agroecosystems. For example, the farm household, the lowest level in the social system hierarchy, is intermediate in spatial scale between the field plot and landscape levels of the ecological scale. Thus, it can be seen that the hierarchies of systems scale at some levels are not isomorphic.

In this paper, land-use change is described at two levels in the ecosystem hierarchy (plot and the landscape) and two levels in the social system hierarchy (the community and the region). Analyses of change at different scales can give a more comprehensive understanding than those conducted at a single scale. Analyses of land-use change at a macro level, such as the region, provide an overview of "when," "how much," and "how" changes occurred, and also allow identification of prominent factors causing the changes. Analyses at a more micro level, such as a landscape, provide more detailed perspectives on land-use events that have occurred in a particular parcel of land. Information from both scales can be compared to reveal the inter-relationships among changes that have occurred at different levels. For example, analysis at the regional level might reveal that there is extensive land degradation in the region as a whole, but at the plot or landscape level it might be found that the degradation has occurred in only some types of fields (e.g., upland fields) but not in low-land fields. Similarly, it might be found that growth of population was a major force for change at the regional social scale but that, within specific individual communities population had stabilized and other factors, such as adoption of commercial agriculture, were the major force for change. Therefore, generalizations on land degradation should not be made across the board and recommendations of ways to rectify the situation should be restricted to specific levels in the systems hierarchy.

The regional level analysis employs secondary information available in the literature, while those at the community, landscape, and filed plot level are based on both the literature review and primary data obtained from our studied village of Kham Muang in Khon Kaen province.

The primary data at the village, landscape, and plot levels were obtained as a part of site characterization activities performed in 1997–98 followed by continuous monitoring until 2001, to describe and analyze biophysical, and socio-economic characteristics of the selected site for our research project entitled "Land-use pattern and associated land degradation in a mini-watershed in undulating terrain of Northeast Thailand." The study was conducted at three levels or spatial scales, i.e. village, landscape (mini-watershed), and field plot levels. The village-level study employed semi-structured interview technique which consists of many interviews of key informants including, among others, the village headman, assistant village headman, former principal of the village school, and some senior citizens who were knowledgeable about various physical, biological, and socio-economic aspects of the village. The landscape-level study employed a similar technique to that of the community level but the informants were those who actually cultivated the land selected for the study site and those in its vicinity. In addition, at the landscape level, data were collected using various types of technical instruments to make physical measurements, such as global positioning system (GPS) and a geological technique of seismography to identify the parent rocks of the study site, etc. The plot-level study employed observations, soil and plant sample collections for laboratory analyses, and physical measurements using various kinds of scientific field equipment.

The analytic framework of this paper (Fig. 1) is based on the contemporary land-use change during the past century occurring at all socio-ecological scales in Northeast Thailand. Distinct phases can be identified in the overall shift from forest to agricultural land use. During the transition between forest system and agricultural systems, many inter-actions among components belonging to the two types of ecosystem also occurred, for

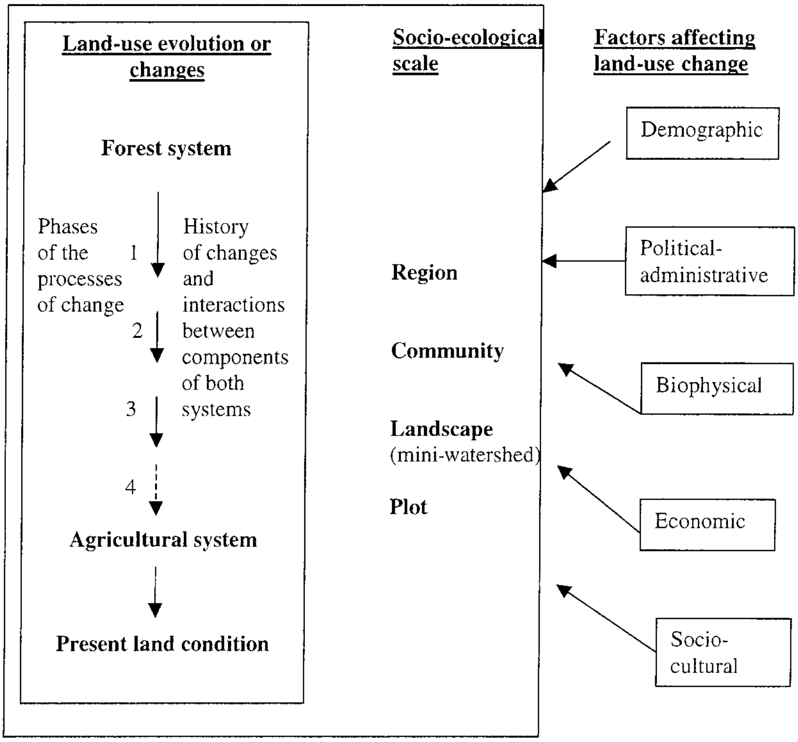


Fig. 1 Framework for the Analysis of Land-use Change in Northeast Thailand

example, people still obtained a lot of forest products for their livelihoods during earlier stages of land-use evolution, and livestock raising relied more on grazing in the forest in an early stage than in a later stage. We have also tried to identify prominent factors affecting the land-use changes at various scales. Some of the possible factors are of demographic nature as population growth has been found to be a most influential factor for peoples' relocation to find new land to make their living, while physical and biological factors are probably related to the population growth when people found that the land they had was no longer adequately productive and other physical and biological resources were no longer available in sufficient quantities to support their growing families. The political and administrative factors at national and local levels can be highly influential in shaping land use through issuing policy, enacting laws and rules of conduct that can directly or indirectly favor one kind of land use over others. For example, the law that prevents secure land ownership does not encourage sustainable land use, e.g. people tend to plant short-term crops in recently cleared land and do not want to plant perennial crops, such as trees, as they cannot be sure that in the future they will be permitted to harvest their crops. Economic factors tend to exert their influence from higher levels in the system hierarchy, e.g., global and national, to lower levels, e.g., regional, community and household. The change from a subsistence-oriented economy to a market-oriented economy is a case in point. The force of market economy infiltrated into Thailand from international market, for example the demand for cassava as a raw material to produce animal feeds by European market. The economic factor to a large extent influences the political factor. For example, the government, in a drive to get export earnings, reshaped its policies to favor the cultivation of cash crops. This resulted in rapid decrease of forested areas that were turned into cultivated fields in the Northeast. Lastly, sociocultural factors related to the Northeastern people's way of thinking, their beliefs and their customs as derived through generations, play an important role in land-use change. Some studies and accounts [e.g., Fukui 1993] have presented the Northeastern people as pioneers who venture into unknown frontiers in the hope of finding better living situations. All of the above mentioned factors not only influence the land-use change on their own, but also interact with each other in complex ways. Overall, however, they have acted so that land-use change in the Northeast in most respects has resulted in degradation of much of the cultivated land. In this paper we will examine the changes that have occurred at different levels in the socio-ecological hierarchy, beginning with a regional overview and then examining changes at the community, landscape, and field plot level in turn.

III Land-use Change in the Northeast at the Regional Level

Contemporary land use in the Northeastern region of Thailand has been a subject of research since the 1930s. Before it was brought under Thai administration in 1830 the region had a very sparse population [Dixon 1978] and the land was covered with dense forest. As late as 1930 only 6.9% of land area was occupied by agriculture which was practically all irrigated [Zimmerman 1937, see also Fukui *et al*. 2000]. The rest of the land was under forest. Zimmerman also pointed out the high potential for expansion of non-irrigated agriculture in the Northeast and this has become the dominant form of Northeast agriculture today. Land-use change in the Northeast is characterized by deforestation due mainly to agricultural expansion which is a common feature of the land-use development in the Mainland Southeast Asia. The greatest pressure for land conversion in Mainland Southeast Asia during 1880–1980 derived from pioneer peasant farmers clearing land for wet rice paddies [Richards and Flint 1994].

Rice is the primary subsistence staple for the population of the Northeast. Production of adequate rice for household consumption is a main factor of food security of the region's population. Rice paddies were usually established as soon as a group of migrants decided to settle in a new location that they found suitable. The first paddies to be established were usually located in the low-lying parts of the undulating terrain that is the dominant land form [KKU-Ford Cropping Systems Research Project 1982]. Preferred sites were the bottom part of a mini-watershed or in a stream channel where water is amply available and the soils are of alluvium deposits which are more fertile than the typically sandy textured soils of upper-lying areas. The villages of the region are usually located on higher lands adjacent to rice paddies in the low-lying areas.

There are conflicting reports about the order in which different types of fields were brought into cultivation in the initial stage of village establishment. Theerasasawat *et al.* [1990] reports that upland rice was cultivated before paddies were constructed because it does not require elaborate bund construction and removal of tree stumps. It was only at a later stage, when weed infestation became overwhelming, that planting of paddy rice began. Other reports, however, claim that wet rice was cultivated first in the low-lying area in the initial stage of settlement establishment [e.g., Dixon 1978]. Recent work on evolution of rain-fed rice cultivation in Northeast Thailand has highlighted the existence of earthen dams during the early period of twentieth century (approx. 1902–41). The dams were constructed across stream channels for the purpose of diverting storm-flow into adjacent paddy fields [Fukui *et al.* 2000]. The diverted or spilled-over water from the dams only reached paddy fields situated in low-lying bottom land of the undulating terrain. This evidence seems to support other studies which found that lowland wet rice cultivation was established prior to other forms of rice cultivation.

Upland crops are grown on higher areas where submerged conditions do not take place. In the early period of a settlement establishment, subsistence upland crops like native cotton, kenaf, and upland rice were grown. Shifting cultivation in the upper-lying areas was reported to be commonly practiced during the 1930s and 1940s [Pendleton 1943]. This was when population pressure on land was still not heavy. Shifting cultivation was practiced on both steep hillsides and upper-lying lands adjacent to the settlement (village). However, Pendleton [*ibid.*] pointed out that shifting cultivation on the latter land did not give as good yields as that on the hill slopes. By the early 1960s, the area under shifting cultivation was reported to be one million hectares [Gartner and Beuschel (1963) cited in Donner 1978]. However, it appears that the practice of shifting cultivation had declined long before the 1960s and by 1953 the first farm survey showed that only 3.5% of the region's farm households claimed to practice shifting cultivation [Thomas 1988].

Livestock (cattle and buffaloes) raising is another feature of land use in the Northeast. The Northeast used to export large numbers of cattle and buffalo to central Thailand. Herdsmen brought them south along small trails which were the only means of transport in the past [*ibid.*]. Cattle raising was a prominent land use in the 1930s and 1940s. According to Pendleton [1943] each household had several head. They grazed on the green and dry grasses in the open forests and some palatable trees and shrubs. After rice harvesting they also grazed on the rice stubble. Rice straw was also kept for their feeding in the dry season. The livestock provided manure that was highly valued by villagers for soil improvement. Since they were kept in pens underneath the house at night, large amounts of manure accumulated in the pen. Pendleton [*ibid.*], being a soil scientist, emphasized the importance of manure as a soil amendment used by farmers. Cattle manure in the past was mainly used on mulberry bushes (for silk worm feed) and tobacco grown for home consumption; any extra manure was also used on rice nursery beds [*ibid*.]. Much research on effects of cattle manure on the fertility of the sandy acid soils of the Northeast has shown conclusively that it improves soil fertility by changing various chemical properties of the soil including increasing soil pH, capacity to retain cation nutrients, and contents of various major nutrients [e.g. Vityakon *et al*. 1988a].

The forests surrounding villages of the Northeast play very important roles in villagers' livelihoods. Villagers obtain construction materials, fuel, food (fruits, vegetables, nuts, and herbs), medicines, dyes, resins, and many other products from the forests [Wacharakitti (1987) and Dixon (1978) cited in Thomas 1988]. Trees, partly remnants of the forests that had been cleared for cultivation, in cultivated fields are a prominent feature of the Northeast landscape. Trees are found in both paddy and upland fields. Pendleton [1943] suggested that farmers did not cut more trees than was necessary because they knew that trees can fertilize the soils. This benefit has been confirmed in research on the contribution of trees, especially its litter fall, to soil fertility in areas close to the trees, i.e. under trees' canopies [Sae-Lee *et al*. 1992] and in the fields where trees stand [Vityakon *et al*. 1988b]. Later research has thrown additional light on the reasons why farmers make conscious decision to keep trees in their cultivated fields based on their indigenous knowledge of the useful roles that trees play in their livelihood by providing timber, fuelwood, food and medicine, livestock fodder, and shade for themselves and their livestock [Grandstaff *et al*. 1986; Vityakon 1993]. It has been further suggested by Dixon [1978] that an underlying reason for the retention of scattered trees in cultivated fields is the extensive nature of the Northeast agriculture. Farmers do not invest their limited labor time in totally clearing the land but instead concentrate on expanding the area under cultivation as long as there is more land available for opening up. This is due to the low productivity soils and unreliability of yields.

Mixed gardens (*suan* in Thai) are also a common land use in villages of the Northeast. Thomas [1988] defines this type of land use as mixed plantings of crops for household subsistence needs and for local trading. Traditional food crops include leafy vegetables, chillies, peppers, eggplants, several types of cucurbits and beans, bananas, papaya, and various fruit trees, herbs and spices; tobacco, betel, mulberry, cotton, kapok, leucaena and eucalyptus are common. The locations for the mixed gardens are upland areas of good fertility and moisture including house plots, separate plots inside the village settlement, banks of ponds, paddy fields after the rice harvest, termite mounds, and field hut plots.

The various land uses described above reflected the predominantly subsistence nature of Northeastern agriculture prior to World War II. However, the subsistence nature has gradually changed into more commercialized agriculture. Growing of rice for sale first began on a small scale during the 1920s and 1930s when railway lines were established [Dixon 1978] but increased considerably in the 1950s and after. Cultivation of upland cash crops, which started in the mid-1950s, has deepened the commercial nature of the Northeast agriculture. Table 1 summarizes some prominent events in the course of land-use change at the regional level.

Table 1 Some Prominent Events Related to Land-use Change Occurring during the Twentieth Century in the Northeast at the Regional Level

Year	Key Events and the Type of Economy
1830	The Northeast was brought under Thai administration.
	Subsistence-economy phase
1902–41	Evidence of existence of earthen dams for irrigated paddy rice.
1930	6.9% of total land was cultivated (synonymous with paddies which were mostly irrigated).
1920s–30s	Railway lines established leading to a small amount of commercial rice cultivation.
1930s–40s	Cattle raising prominent. There was an element of commercialization as some cattle were exported to Central Thailand.
1930–53	Shifting cultivation common but by 1953, only 3.5% of farm households still practiced shifting cultivation.
	Commercial-economy phase
1950s	Beginning of commercial upland cash crop cultivation. Rapid loss of forest.

Land-use change in the Northeast region can be attributed to the following factors:

1) Rapid population growth [Thomas 1988; Dixon 1978]. According to Thomas [1988] the population increased during the 65-year period (1920–85) from 3 million to 18 million people. As a result, farmers brought all usable land within existing villages under cultivation and then those who lacked land migrated to frontier areas to establish new settlements.
2) Expansion of the market and increasing commercialization of agriculture [Dixon 1978] arising from socio-political and economic changes at national and international levels. Since the mid-1950s cash crops have been grown increasingly in upland areas where productive paddy fields could not be established [*ibid.*]. As a result, the mixed gardens (*suan*) have been transformed into permanent upland fields [Thomas 1988]. The major upland cash crops grown in the Northeast have been kenaf, maize, sugarcane, peanuts and cassava. Changes in market prices have played an important role in determining the kind of upland crops farmers decide to grow at any particular time. Expansion of upland cropping has increased the area under cultivation and pushed the forest frontier further back.
3) Thai Government efforts to increase the extent of the Northeastern region's socio-economic integration into the Kingdom [*ibid.*]. This started in King Chulalongkorn's period during the nineteenth century in response to the threat of the French imperialism. It was followed by the enactment of National Socio-economic Plans under the administration of Field Marshall Sarit Thanarat in the 1950s and later under succeeding governments. The Northeast received increased attention from the central government partly as a mechanism to counter growing communist movements in the neighboring states. Since the 1950s, thousands of kilometres of strategic roads were constructed in the region. These roads have brought the Northeast villagers into market economy. A few large dams were constructed to provide electricity and irriga-

tion water and also accelerated regional development. Improvement of education and community developments were emphasized.

It can be concluded that land-use change at the regional level in the Northeast has been influenced by biophysical, socio-political and economic factors. All through the twentieth century, land use for subsistence rice growing received priority due to its being the staple food of the people. According to Thomas [*ibid*.] prior to the 1950s, farm holdings were probably considered to be virtually synonymous with paddy holdings. Wet rice was planted in the low-lying areas where water was easily available. Other crops for home consumption and, to a small extent, for sale locally, including cotton, tobacco, mulberry, vegetables, fruit trees and kenaf, were planted in mixed gardens and shifting cultivation fields in the uplands. Biophysical factors, e.g. terrain and crop characteristics, have played an important role in determining agricultural land use. Rapid population growth resulted in the expansion of the cultivated land of the villages. The forest frontier was pushed back as less suitable and more marginal land for wet rice cultivation was cleared. As the region has become more market-oriented due to changes in socio-political and economic factors, cash crops have become increasingly more important and the area devoted to their cultivation has increased further through clearing more forest land. Northeastern agriculture, therefore, possesses extensive characteristics as more land is cleared from forest to increase production as opposed to more intensive use of existing agricultural land to increase production per unit area.

IV Land-use Change at the Community Level

A closer look at land-use change in the Northeast can be taken at the community or village level. Four studies of land-use change in communities in different parts of the Northeast will be discussed, one study of villages in Kalasin province and three studies of different villages in Khon Kaen province.

IV–1 *Land-use Change in Villages in Kalasin Province*

Establishment of a new settlement is a key process bringing about land-use change in the Northeast. Dixon [1978], who studied villages established on relatively low-lying areas in Kalasin province in the central Northeast, equated the formation of a village with land clearance activities to establish paddy fields. He found that settlers first moved into and along the main river valleys taking advantage of the most fertile and reliable alluvial land, with good water supply and river transport. He divided the sequence of settlement into five stages:

In Stage I, the primary settlements were established on dry sites on the flood plain away from the most flood-prone land and adjacent to the lower terrace. The more flood-prone areas of the flood plain were frequently cleared first because of their high inherent fertility, less dense vegetation, and fewer termite mounds. The relatively level land enabled small bunds to be constructed and large fields to be utilized for paddy cultivation.

In Stage II, after settlements were established, the relatively higher-lying land of the floodplain that is less fertile, more heavily forested, but also less flood-prone was cleared. In this stage, settlers moved out of the flood plain and onto the low terrace as the population grew, leaving some uncleared land which was important for grazing, hunting, and collecting forest products.

In Stage III of flood plain settlement, the utilization of dry sites near the rivers and the cultivation of fertile but highly flood-prone land occurred.

In Stage IV, as population continued to grow, the higher and less fertile area of the lower terrace and, later, parts of the upper terrace were cultivated. These areas are less fertile and more vulnerable to environmental hazards, particularly drought. The movement into more marginal areas resulted in increases in the average size of holdings to compensate for the lower yields and as an insurance against crop loss from environmental hazards.

In Stage V the cultivation of upland cash crops, notably kenaf, maize, and cassava, began in the 1950s on land that would have been marginal for paddy. At this stage permanently cultivated upland fields are developed on middle and high terraces. Agriculture became more extensive as more land is cleared for cultivation as a result of population increase and low productivity of land. Once a settlement (village) reached its full capacity in terms of resources available for settlers (one indicator of this is the distance from the village to uncleared land which new settlers could take up), excess people had to migrate to uncleared land elsewhere and form a new settlement [*ibid.*].

IV–2 *Land-use Change in a Village in Undulating Terrain in Khon Kaen Province*

Another study of a village which was established in 1867 in an undulating terrain in Khon Kaen province in 1867 [Subhadhira *et al.* 1988] identifies four stages in land-use change and also presents an analysis of the impact of external forces on the village and the consequent changes in agroecosystem properties. Initially only the low-lying parts of the undulating terrain were cleared for cultivation but gradually, cultivation expanded into upper-lying areas as a result of population increase and cash crop cultivation.

During Stage I of village development (1867–1938), land use was mainly wet rice fields in low-lying areas, mixed gardens in relatively upper-lying areas, livestock grazing in uncultivated upper-lying areas, and forest in the uppermost part which provided various products for villagers' livelihoods. Although most activities were for subsistence purposes, there was a commercial element in selling of cattle to the Central region. This was one of the two external forces influencing the village in this phase. The other force was the in-migration of people from other areas in the Northeast. The village is considered to have high self-reliance, and autonomy and satisfactory productivity at this stage.

In Stage II (1938–60), the village saw an increase in population due mainly to in-migrations which continued until 1943. The population increase resulted in a decrease in the land-to-people ratio. This led to emigration to find more cultivated land leading to the formation of a new settlement close-by. Commercialized agriculture increased as seen by exporting of glutinous rice to other Northeast provinces using carts and river transport, a short period of cotton trading to the Central region during World War II, and expansion of kenaf cultivation as cash crop beginning in the 1950s. These activities resulted in expansion of cultivated land through further clearing of the forest. The decrease in the area of forest land resulted in decreasing nutrient availability and soil organic matter in the fields and a decline in the supply of natural foods and other products obtained from the forest within the village system. Forest products were replaced by some importation of consumer goods and foods. The village at this stage became less subsistence oriented and more influenced by external forces related to market economy. Its self-reliance became lower. In addition, its autonomy also decreased due to the central government's intervention in village affairs.

In Stage III (1960–79), the village became more accessible due to road construction and was more influenced by more external forces than in the past. In addition, its relationships with outside forces moved up the hierarchical level from provinces within the Northeast to the Central region and the world market. There was an expansion of kenaf cultivation as a cash crop into the forested area in the northern part of the village. The number of livestock decreased due partly to reduced availability of grazing land in the forest. Kenaf was the major cash crop grown for export but some non-glutinous rice was also grown as a cash crop. During this period, cassava was introduced as another cash crop. The cultivation pattern in permanent upland fields became increasingly monocultural as the more diversified mixed gardens were gradually replaced. Rapid expansion of cultivated areas into the forest was seen in this phase. Rice cultivation was expanded into upper-lying areas which resulted in constructions of earthen weirs and ponds to supply water for rice cultivation. Chemical fertilizers began to be applied at this stage to maintain productivity which otherwise would have been low due to nutrient depletion in the system.

In Stage IV (1979–84), continued expansion of cash crops occurred. A new cash crop, i.e. vegetables for seed production, was introduced in low-lying areas. This required high input of labour, chemical fertilizers and pesticides. Moreover, more ponds were constructed for fish raising as natural fish became scarcer. At this stage, villages became more dependent on external resources for even such basic necessities as food and agricultural inputs (chemical fertilizers, pesticides).

From Stage I to IV, the village experienced decreasing self-reliance and growing loss of autonomy. Productivity was maintained or increased by relying on external resources, such as chemical fertilizers.

IV–3 *Land-use Change in a Village in Undulating Terrain with a Prominent Floodplain in Khon Kaen Province*

A very detailed agroecological study of a village in Khon Kaen province was conducted by an interdisciplinary Japanese-Thai team in 1981 and 1983 [Fukui 1993]. The settlement was established sometime before 1871 when it was officially recognized as a village by the government. The settlement was situated at the edge of high ground of the typical Northeast undulating terrain overlooking the floodplain of the Chi River where most of the paddy fields were established. The rest of the paddy fields were in the upper-lying areas intermediate to the uplands. Paddy fields were the first agricultural land use practiced by the early immigrants. They first opened up lands in depressions (*nong* in Thai) of the undulating terrain but left aside the bottom lands that had poor drainage for later conversion. Almost all of the lower parts of the depressions had been developed by the mid-1930s and accounted for slightly over half of the paddy area in the 1980s. The expansion of paddy areas from lower parts towards the edge of the depressions began in the 1940s in response to population growth. This expansion took a much shorter period than that of the low-lying paddy fields during late the 1930s and the 1940s. The expansion was into less productive land but since this new upper-lying land was a supplement to the older more productive paddy fields all households reclaiming land owned both types of paddy fields. Fukui [*ibid.*] was reluctant to call this process of combining the less productive newly-acquired land with the old more productive paddy field, *expansion of arable land,* and he opted to call it *expansion of supplementary arable land*.

Fukui [*ibid.*] has related changes in the village land use to changes in its population that occurred in three stages. In Stage I the process of village development consisted of in-migration of people from near-by areas, approximately 60–100 kilometers away. The founding population of the village was 50 people. Studies on demographic history of the village since 1900 have shown that during the initial stage of village development (1900–19), in-migration was predominant. In Stage II (1920–34), in-migration and out-migration balanced; and in Stage III (1935–83), out-migration was predominant.

The main reason for in-migration in Stage I was "land pioneering" to find new land for paddy rice cultivation. This generally involved movement of entire households. The land-use activity during Stage I was the opening up of land in the lower parts of the depressions to establish paddy fields. This had been practiced as early as late nineteenth century by each group of early immigrants who were mainly groups of kinspeople from the same place of origin. The last large group of immigrants to have settled in the village arrived in 1916 [*ibid.* : 60]. Each group came to occupy its own *nong.*

In Stage II, the opening up of the new land in lower parts of the depressions continued until the supply was exhausted after which the clearance of upper-lying fields began. At the end of this period, population outflow took place concurrently with the opening up of the less productive new paddy land. Emigration at this stage was mainly in order to find new land for paddy fields (land pioneering) as population pressure began to be felt. In the first 40 years of Stage III (1935–74), emigration for purposes of land pioneering intensified leading to the formation of a new settlement that became a "daughter" village.

Upland cash crop cultivation was started on a small scale in the village during WWII when cotton was planted in response to demand created by a sudden reduction in raw cotton imports. Since the village was situated in the floodplain topography, however, the upland area was much smaller than the area of paddy land. In the 1980s the ratio of area occupied by paddy land to that of upland was 100:19 [*ibid.* : 56]. Cotton was cultivated by slash-and-burn method on upper-lying land cleared from the existing sparse forest and scrub. A plot was cultivated only once before it was abandoned. The practice was short-lived as a result of the end of the wartime boom. Major upland crop cultivation started in the mid-1950s with kenaf and was followed by cassava in the 1960s. Both crops were aimed at the export market. Kenaf was initially cultivated on the abandoned cotton swiddens. It was reported that its cultivation led to the first recognition of the ownership of the upland fields [*ibid.*]. The cultivation of these cash crops led to major deforestation in the upland area of the village so that by the late 1960s almost all the wooded land around the village that had remained in the mid-1950s had disappeared.

IV–4 *Land-use Change in Kham Muang Village*

The village of Kham Muang was selected in 1997 as the study site of our project on "Land-use pattern and associated land degradation in a mini-watershed in undulating terrain of Northeast Thailand." The village-level study employed a semi-structured interview technique as described earlier in the Methodology section.

Kham Muang village (Ban Kham Muang) is situated approximately 45 kilometers north of Khon Kaen city and 6 kilometers from the municipality of Khow Suan Kwang (Fig. 2) and is conveniently accessible by a concrete road.

Kham Muang village is situated in deeply undulating terrain typical of the topography of

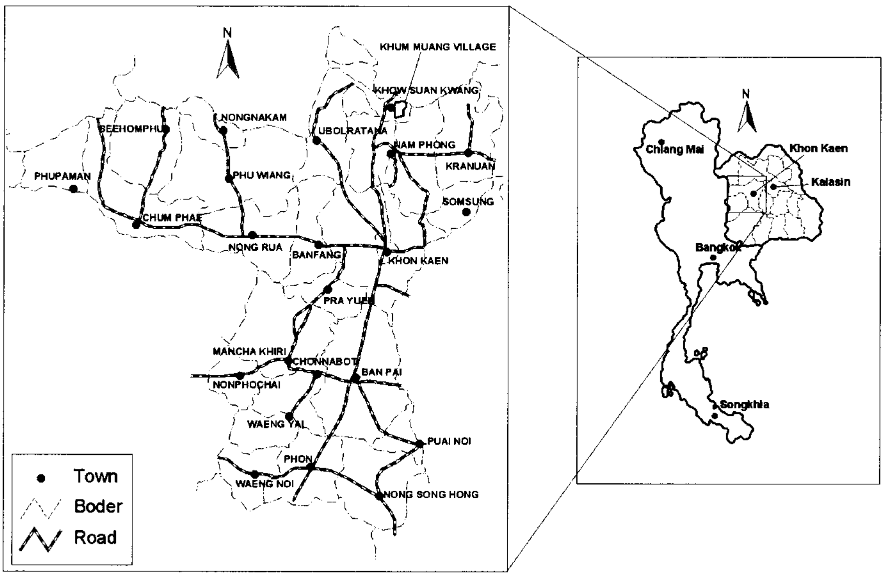


Fig. 2 Location of Kham Muang Village

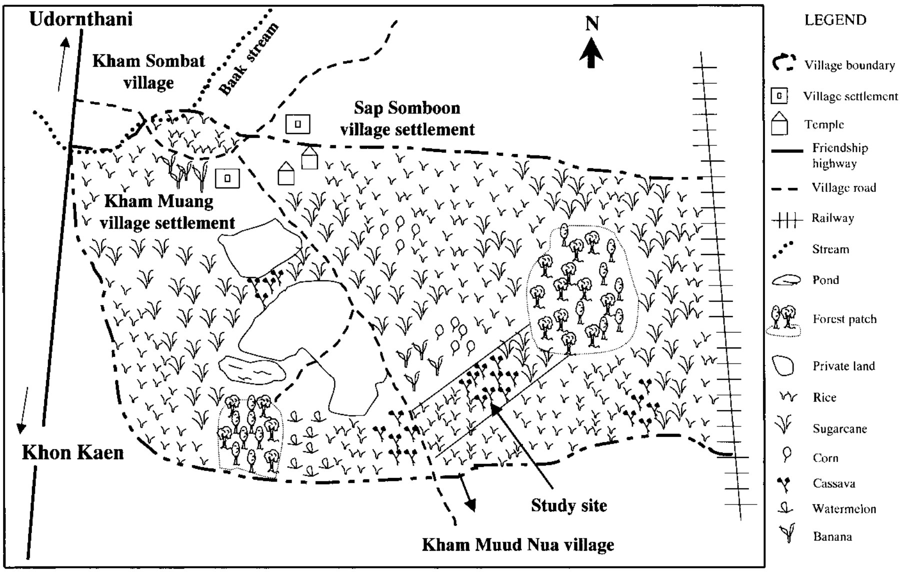


Fig. 3 Boundaries and Land Use in Kham Muang Village in 1998

the Khorat basin. It has an area of 3,600 *rai* (576 hectare, 1 ha = 6.25 *rai*). The settlement is situated on upper-lying area overlooking paddy fields on adjacent lower-lying area to the west. The settlement occupies 475 *rai* (76 hectare) or 13.2% of total land area. Agricultural lands occupy 2,500 *rai* (400 hectare) or 69% of total land area. They were located to the east and west of the settlement (Fig. 3). The eastern part is deeply undulating while the western part is relatively flat lowland. The ratio of area of upland fields to lowland paddy fields is 3 : 2. Public lands, mainly the cemetery and reserved land (forest), occupy 529 *rai* (84.6 hectares) or 15% of total village land. The average household land holding is 18 *rai* (2.9 hectares). There were 5 landless households out of the total number of households of 137.

Kham Muang village was founded approximately in 1889. The first group of people who settled in the area was composed of livestock merchants-herdsmen and their families from Roi Et province to the southeast. In the course of their searching to buy livestock, they found an upland area covered with lush forest vegetation with springs from shallow groundwater which appeared to be available all year round. This was considered a good place for a new settlement, which they named Ban Kham Muang (Ban in Thai means a community) because of the presence of numerous native mango trees (*mak muang* in Thai) in the area. More than 10 years after the first group of pioneers arrived, several other groups came to settle including those from Nam Phong and Kranuan districts of Khon Kaen province, and Kosum Phisai district of Maha Sarakham province.

The original settlement was situated on the edge of the upper-lying area overlooking a low-lying area. However, after a disease epidemic, the village was moved to its present site which is nearby the original one.

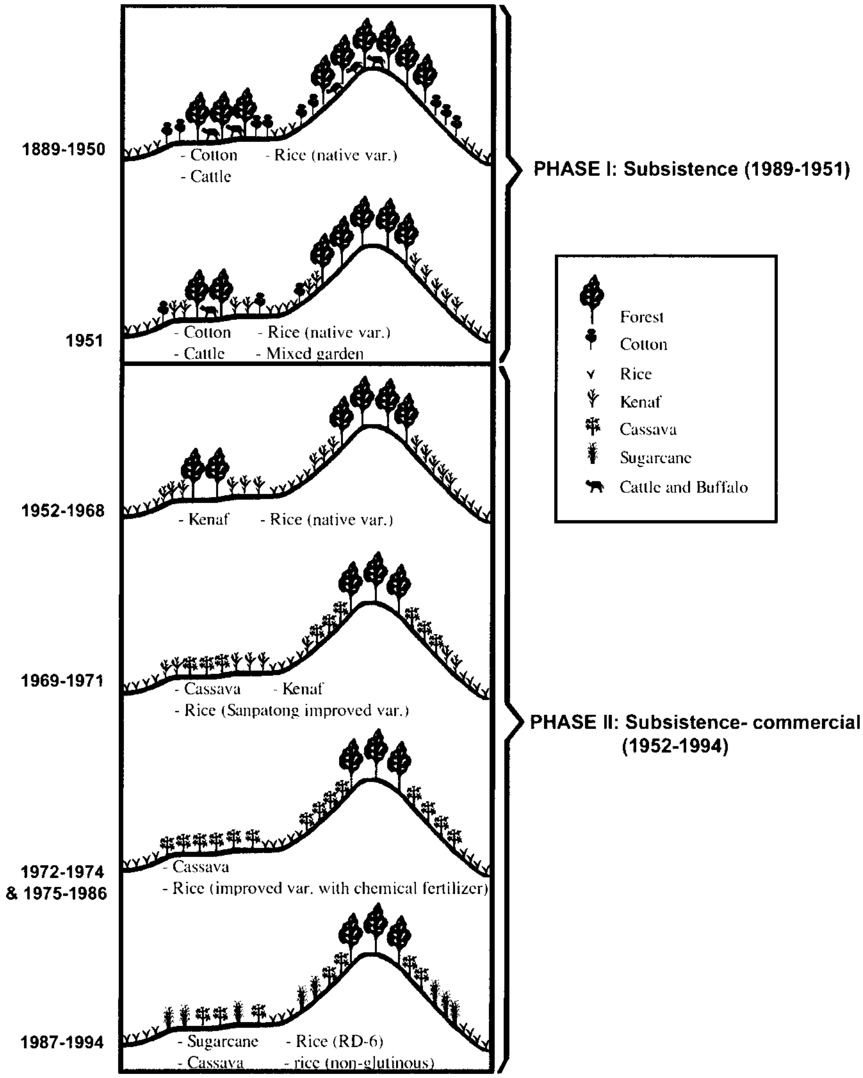


Fig. 4　Stages of Land-use Change in Kham Muang Village

The pattern of land-use change in Kham Muang village from its formation is broadly similar to that of the other villages in the Northeast that have already been described. Based on information from key-informant interviews, such changes from 1889 can be divided into three stages (Fig. 4) as follows:

IV–4–1 *Stage I (1889–1951): Subsistence Stage*

Land use by villagers during this stage was mainly for subsistence purposes. The land area can be divided into three zones according to the land use as related to the terrain (Fig. 3).

The first zone was low-lying areas found in the depression of the undulating terrain initially along the Huay Baak (Baak stream) to the southwest and northwest of the present settlement. Huay Baak was the major drainage channel of the village. Villagers opened up this land to grow native glutinous varieties of paddy rice for home consumption. After all the land around Huay Baak was used, low-lying areas in the depressions to the east of the settlement were opened up for paddy rice. The second zone was the upland part of the undulating terrain where some field crops were grown for subsistence. The most important field crop during the early period of settlement formation was cotton, the fiber of which was used for cloth weaving. The third zone was the undisturbed upper part of the undulating land near the village that was covered with forest. The forest zone was used to raise buffaloes and cattle. The forest also provided natural foods, fuel, timber and medicinal plants for the villagers. Another type of land use in this period was mixed garden found in various zones but mainly on the upper grounds of the paddy field areas. The grown crops included native melons, tobacco, and sugarcane for home-made sugar. Cotton was also grown on termite mounds in paddy fields in the form of mixed garden.

As population grew, there was expansion of the paddy fields from the lower parts of the depression onto relatively higher areas on the edge of the depression or towards the upland. This area is marginal for paddy rice from the standpoint of soil fertility and water availability as compared to the area in the lower part of the depression.

In this stage, crop production was guided by indigenous knowledge. Soil fertility was sustained by natural fertilizers in the form of weeds, crop residues, animal manure, and leaves and debris from the forest. Cropping patterns that maintained soil fertility were practiced, such as crops rotated with fallow periods. Land preparation and transport were performed by draught animals and human labor.

IV–4–2 *Stage II (1952–94): Subsistence-commercial Stage*

This period can be divided further into three sub-periods based on the introduction and spread of major commercial crops and the increasing degree of adoption of high-input agriculture, i.e. Stage IIa (1952–68), Stage IIb (1969–86), and Stage IIc (1987–94).

During Stage II, land use in agriculture changed from having a full subsistence-orientation to being semi-commercialized as a result of road construction starting in the mid-1940s that brought the village into more contact with the outside world. During this stage paddy rice was planted in the low-lying areas and some parts of the upper-lying areas. It was mostly raised for home consumption but any surplus was sold. In the Stage IIa (1952–68), growing of cotton in the upland area was gradually replaced by kenaf. Kenaf was first introduced in 1952 when the villagers started to grow kenaf on a small area (less than 1 *rai*). However, the growing area gradually increased. In 1968, an agricultural produce enterprise in Khon Kaen city promoted kenaf planting by providing seeds and buying the produce. Kenaf cultivation led to greater forest clearing.

Stage IIb (1969–86) saw greatly increased village involvement in commercial and high input agriculture. In 1969, a new cash crop, cassava, was introduced by a pioneer grower in the village who brought it in from the outside. It gradually replaced kenaf as the main cash crop. By 1973–74 kenaf cultivation had declined dramatically due to rapid expansion of cassava. Cassava was the dominant cash crop until 1986 and its cultivation led to further forest clearing. In addition, a new improved glutinous variety of rice, Sanpatong, was introduced in 1971 to replace the native varieties. In 1977, chemical fertilizer was introduced by the agricultural extension office. The fertilizer formula was initially 16–20–0, later it was changed to 15–15–15. It was initially applied to paddy rice at low rates (approximately 10 kg per *rai*) which is 2.5 times less than the present rate.

In the Stage IIc (1987–94), even more commercialized and high input agriculture was adopted. In 1987, another new improved glutinous rice variety, RD 6, was introduced by the local agricultural office. It gradually replaced all the native varieties in subsequent years. Around this time non-glutinous rice began to be cultivated in the village. The variety was aromatic Khao Dok Mali 105 or jasmine rice. Its adoption reflected the changing cultural values of the villagers as members of the younger generation, who, as a result of their exposure to external influences through schooling and travel outside of the village, tended to adopt non-glutinous rice for their diet. The non-glutinous rice was also grown for sale. During the same year, sugarcane was planted in the village in response to the market created by the construction of a sugar refinery in nearby Nam Phong district. During this stage, cassava and sugarcane were about equally dominant on the uplands. Choice between growing each of the two crops was determined by market prices of the crops, size of land holding, and capital input. The continuous growing of upland crops led to soil degradation as indicated by yield decline. Starting in 1994, 15–15–15 combined chemical fertilizer had to be applied to cassava at the rate of 50 kg per *rai*. One way to alleviate yield decline in cassava was to rotate it with sugarcane because the residual fertilizers from previous crops of sugarcane and its organic residues, especially from sugarcane roots, brought about an increased yields in the subsequent cassava crop.

Encroachment of both cassava and sugarcane led to a decrease in the forest area of the village. By approximately 1987, the village forest area of 2,000 *rai* was reduced to approximately 400 *rai*. This prompted the village administrators to institute conservation measures. As a consequence of the forest decline, the number of buffaloes and cattle gradually decreased due partly to the lessened availability of forest and vacant uplands for grazing.

In Stage II high-input technologies for agriculture were increasingly adopted as a consequence of the shift from subsistence to more commercialized agriculture. These high-input technologies included the new improved varieties of rice, chemical fertilizers, and two-wheel hand tractor for ploughing. These tractors replaced draught animals contributing to a further decrease in the number of buffaloes and cattle and thus a reduced supply of organic manure in the village.

IV–4–3 *Stage III (1995–97): Removal of Land from Agricultural Use to Construct a Private Housing Project*

In 1995, the upland agricultural area was reduced by the sale of a parcel to land speculators who intended to convert it into a commercial private housing project. However, the progress of this type of land use was hampered by the economic crisis beginning in 1997 so the land was left idle. In the future, however, when economic growth resumes in the Northeast, more land may be taken out of production for housing and industrial uses.

IV–5 *Some Common Characteristics of Land-use Change at the Village Level in the Northeast*

It can be seen from the various village studies presented above that biophysical, demographic, economic, and sociocultural factors all influenced the process of land use change. In all cases selection of land to develop at the founding of a settlement was decided initially on biophysical grounds, i.e. the most productive land was invariably selected first. With subsequent population growth, more peripheral, less productive land was brought into use. This has been found to be a common pattern [Fukui 1993: 309]. Our studies in Kham Muang village provide results that substantiate the above statements. It was found that paddy fields were established first in the fertile lowland with alluvial soil along the major stream channel of the village. Later after the best land was used up, the less productive land in the low-lying areas but away from the major stream was brought into use. As population grew, there was expansion of the paddy fields from the lowlands into relatively higher areas. Economic factor, notably the change from subsistence to partial market economy, was a major influence on land-use change in all villages. In Kham Muang village, starting in the mid-1940s there was some road construction that brought the village into more contact with the outside world. By the early 1950s kenaf as a cash crop began to replace cotton. Kenaf could be sold to some local commercial enterprise. The prominent socio-cultural characteristic resulting in the land-use change at the village level is "the land pioneering" habit of the people which led to establishment of new settlements in areas still covered by forest. Settlement establishment is characterized by land clearance. The sequence of settlement described by Dixon [1978] and illustrated by examples of subsequent work by other researchers, gives rise to clustered nature and, as described by Sternstein [1965], spatially even distribution of settlements in the Northeast.

V Land-use Change at the Landscape (Mini-watershed) Level: A Case Study at Hom Bak Heb Mini-watershed

A "mini-watershed" in the undulating terrain was selected as a representative unit of land use for the study of land-use change at the landscape level. The site is located in the southeast part of the Kham Muang village, 2.5 km from the settlement (Fig. 3). It is situated between the latitude of 16°48'–16°49' north and the longitude of 102°52'–102°53' east. The mini-watershed is located in an area locally known as Hom Bak Heb.

V–1 *Area and Boundaries*

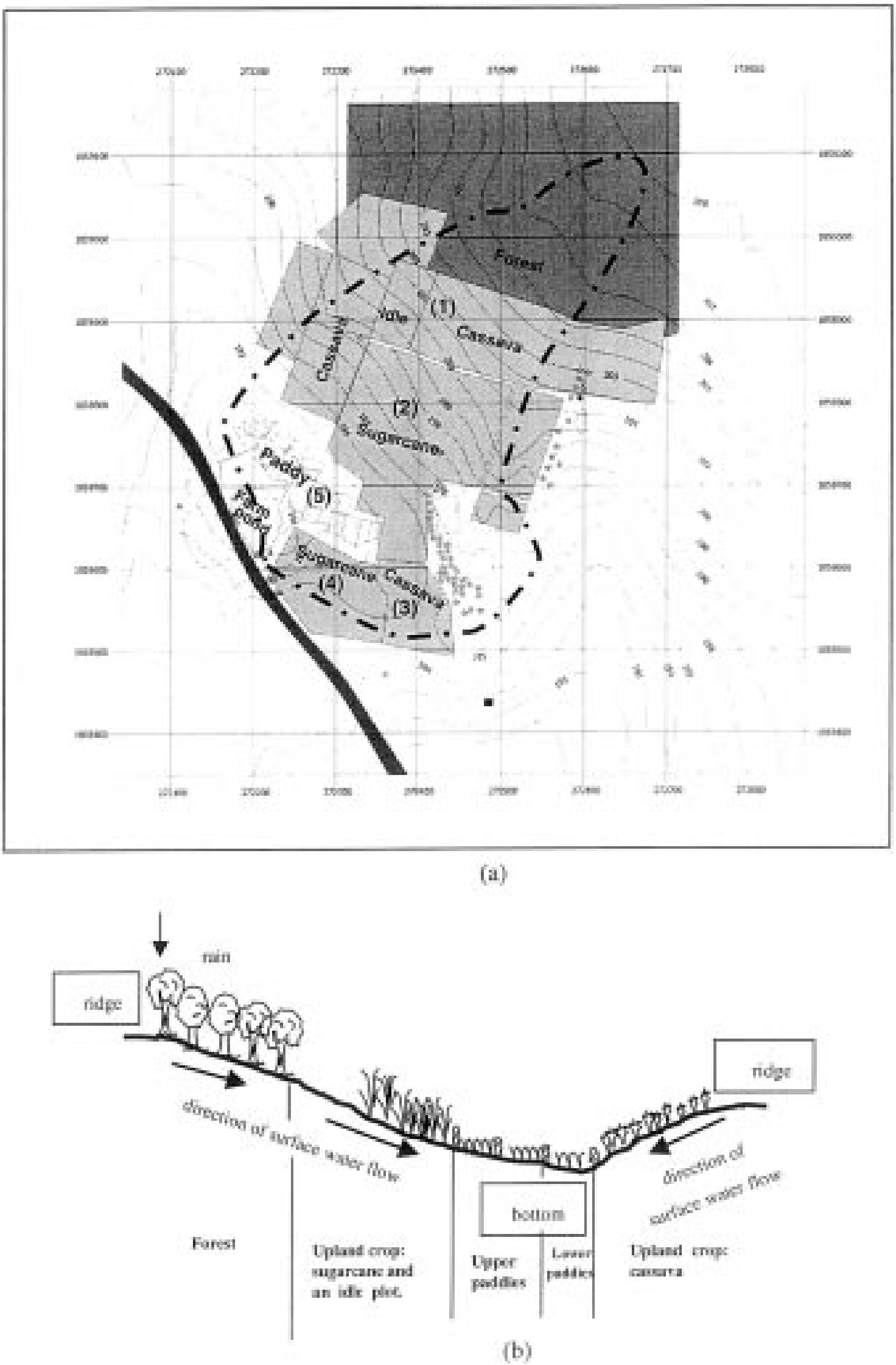
The total area of the mini-watershed is 88 *rai* (14 hectares). The longest part was in the north-south direction which was 600 m, while the widest part in the east-west direction was approximately 250 m (Fig. 5a). The northeast boundary was a forest reserve. The southern boundary is a dirt road connecting Kham Muang village with a neighbouring, Kham Muud Nua village. The eastern and western boundaries are cultivated land of Kham Muang village (Fig. 3).

V–2 *Landform, Geology and Soils*

The name *hom* in the Northeastern language indicates a depression or a kind of landform that resembles a saddle or a small valley consisting of the bottom part and the upper-lying part located on the upper slope. This kind of landform is considered a mini-watershed as the water flows from ridges at the topslopes which form the watershed boundaries down to the bottom part (Fig. 5b). There used to be a stream running in the low-lying part of the mini-watershed before it was transformed into paddy fields. Hom Bak Heb mini-watershed has gently undulating terrain with an average slope of 2.8% in the north-south direction. The elevation at the lowest part is 190 m above sea level (asl) and 208 m asl. at the uppermost point in the forest reserve (Fig. 5a, b).

Geologically, it consists of a layer of bedrocks situated at a 10–12 m depth below the soil surface (information from seismographic study). The bedrock is laid out in an almost parallel fashion to the surface topography. Most of the rock is sandstone with some shale inclusion. The rock belongs to the Khok Kruat formation (Kkk) which was formed during Cretaceous geological period (Groundwater map of Khon Kaen province, Dept. of Mineral Resources). Information on surface lithological compositions down to 8 m obtained through drilling of 9 bore holes showed that it has sandy to sandy loam textured soil down to 0.8–1.30 m below which it became clay. There are layers of laterite and materials of gravel size below the clay layer.

Soil profile studies showed that the soils were derived from alluvial parent matrials of sandstone origin. In general, the soils have a coarse texture (loamy sand to sandy loam for the upland soils and sandy clay loam for the lowland paddy soils). Where there is no clay accumulation at approximately 1 m depth, they were considered Great Group Quartzipsamment (Soil Taxonomy system of soil classification), however, if there is a horizon of clay they belong to the Great Group Paleustult. They were three soil series found. The paddy soil belongs to the Ubon series (Aquic Quartzipsamment) and the upland soils belong to the Khorat series and Satuk series (Oxic Paleustults). An interview with a farmer-owner of part of the land in the mini-watershed revealed that he classified the soils in the mini-watershed into three types: black soil (mainly in the bottom of the lowlands), sandy soil (the most dominant in the mini-watershed) and stony soil (low coverage—approx. 10%). It can be seen that



(a)

(b)

Fig. 5 The Mini-watershed: Boundaries (Thick Broken Line), Contour Lines (Thin Solid Lines) and Land-use Plots of Different Kin Farmers (Indicated by Number in Bracket) in 1998: (a) Top View, and (b) Cross Sectional View the farmer used texture and color as two prominent criteria to classify the soils. This farmer classification matches with the scientific one most closely from the viewpoint of soil texture. Sandy soils, notably topsoils, predominate in the mini-watershed. However, the color criterion, i.e. black soil, was not used in the scientific classification. This is likely because the black materials are some finer-than-sand materials consisting of some silt and clay with organic matter that form a thin layer on top of coarser materials. These materials are washed from the higher grounds and deposited in the lowlands. This does not influence the scientific classification.

V–3 *Land Use and Land-use Change*

Land use in Hom Bak Heb mini-watershed in 1998 consisted of forest and agriculture. A patch of forest remained in the northernmost part of the mini-watershed. It was a part of the 400-*rai* reserved forest of the subdistrict. It was dry dipterocarp forest commonly found in the undulating terrain. The dominant species was *Dipterocarpus tuberculatus* (*pluang* in Thai).

Agricultural land use in Hom Bak Heb mini-watershed at the time of the study (1998) involved five households. Three of these households were related through kinship, i.e. plot 1 was used by Mr. Bunmee, the eldest son-in-law to the legal owner (Mrs. Suk); plots 2 and 4 by Mr. Kong, her young son-in-law; and plots 3 and 5 by Mr. San, her youngest son (Fig. 5a). Interviews with some farmer-land-owners revealed the history of the land use in the mini-watershed from the time of their ownership. The present land owner (Mrs. Suk and her husband) bought the land in Hom Bak Heb from a previous land owner in 1960. The land in Hom Bak Heb had earlier been under forest. At the time of the land-ownership change, the lower part of the land, including the bottom and the lower part of the upland, had been opened up for agriculture by the previous owner, however the forest in the upper part was still relatively intact. Forest clearance occurred from the lower parts upward. The lower-lying area adjacent to the southwest border of the watershed was cleared first for paddy field construction followed by the lower parts of the upland fields (e.g. plots no. 2–4 in Fig. 5a). This definitely occurred before the land sale in 1960 and may have occurred in the early 1950s as the previous owner had cultivated kenaf prior to the selling of the land and it is known that kenaf was first cultivated in the village in 1952 (Fig. 4). Kenaf was cultivated by the family in plot no. 2 (Fig. 5a) for 14 years until 1974 after which cassava was cultivated continuously until 1987 when sugarcane was introduced.

The upper-lying part of the upland in Hom Bak Heb (plot no. 1 in Fig. 5a) was cleared in 1969 when the family acquired a new son-in-law by the marriage of the eldest daughter. The land was cleared by the eldest son-in-law for kenaf cultivation. By the early 1970s kenaf was replaced by cassava.

Land use was extensive rather than intensive as the result of new land being brought under cultivation in upper-lying areas of Hom Bak Heb watershed. Cash crop cultivation alternated with periods of fallow in the early stage as long as there was new land available for opening up. The planting of upland crops in the newly-cleared land signified the intention to own the land.

Sugarcane was introduced in 1987 but did not replace cassava in the same way the latter did with kenaf. Both crops became major cash crops and were grown in Hom Bak Heb mostly alternately in a 2-year cycle; however crop price is a major factor determining whether farmers opt to plant cassava or sugarcane at any particular time. The alternate pattern of growing sugarcane and cassava is also done to help maintain crop yields through rotation. It was found that cassava grown after sugarcane produced better yields than continuous cassava because the residual chemical fertilizers from sugarcane and the organic residues left behind after the cane is harvested improved the fertility of the soil. Crop prices, however, are a more important factor in determining the kind of cash crops to be grown. Watermelon was another cash crop grown in rotation with cassava and sugarcane in the mid-1990s. It required relatively high inputs of fertilizers and pesticides. However, watermelon was abandoned due to the health hazard to the growers caused by the pesticides used.

The paddy fields at the low-lying part of the mini-watershed were planted totally to the RD6 glutinous rice for home consumption at the time of the study (1998). In 1992, the bottom part of the depression was turned into a farm pond for fish raising for consumption.

VI Effects of Land-use Change on Biophysical Characteristics at the Landscape and Plot Levels

Biophysical studies conducted at the plot and landscape levels (under our project "Land-use pattern and associated land degradation in a mini-watershed in undulating terrain of Northeast Thailand"—LDP) have revealed that land-use change has brought about land degradation notably in the upper-lying part of the mini-watershed, while the lowland paddy fields are not considered degraded. The indicators used to show land quality changes were comparative soil erosion and soil organic matter characteristics under the forest (the original land use) and agricultural field plots. Soil erosion was significantly higher in the upland field crops system than the forest system, for example in the year 2000, soil loss in the forest plot was 1.8 t/ ha/yr while the loss in the cassava and sugarcane fields was approximately 20 t/ha/yr (LDP, unpublished data). The upland field crop erosion value was well beyond the soil loss tolerance value of the US Soil Conservation Service of 10–12 t/ha/yr. Nitrogen (N), phosphorus (P) and potassium (K) losses through erosion in the same year were also much higher in the field crop plots than in the forest, i.e. (in kg/ha of nutrients) in the cassava plot: 15.5 N, 3.2 P and 7.1 K; in the sugarcane plot: 8.2 N, 1.2 P and 3.3 K; and in the forest plot: 1.5 N, 0.2 P, and 0.6 K. The high loss in field crop plots results from their low percentage of ground contact cover and frequent soil disturbance, such as from ploughing, especially during heavy rains. The forest plot had better developed ground cover and the surface was relatively undisturbed.

An interview with a farmer cultivator of part of the land in Hom Bak Heb revealed that he perceived soil erosion as severe. However, the farmer perceived soil erosion to be a problem only because poor quality soil from the upper areas moved downslope to cover better quality soil in lower-lying areas. The phenomenon of soil movement was considered a prominent process that had been occurring in the mini-watershed since the early days of land transformation from the forest. The farmer categorized the soils in the mini-watershed into three types: sandy soil (*din sai*), black soil (*din dum*), and lateritic soil (*din hin kon sao*). Lateritic soil only occupies 10% of the total land area. Black soil, found in low-lying areas, is more fertile than the other two soils. In the past when there was more forest, black soil covered most of the farmer's fields, but it had been steadily decreasing to 20–30%. The decrease was perceived to be due to the flow of sandy soil eroded from the higher areas and mixed with the black soils in the lower areas including paddies. Paddy soil was also black but it had been becoming mixed with sandy soils as a result of sedimentation. The farmer indicated that when there was more forest, there was no flow of sandy soil into other areas.

Another indicator of land degradation used in our study was soil organic matter (SOM). In our study, the SOM of the whole soil, i.e. total soil carbon and nitrogen, and those of fractionated soils (different SOM pools: labile and stable) were investigated in various land-use plots in the mini-watershed [Tangtrakarnpong and Vityakon 2002]. Labile pools, such as microbial biomass, are those that are transformed rapidly, while the stable pools, such as humic substances, are the slowly-transformed part. The study showed that the contents of various pools were higher in the forest than in the upland field crop systems (cassava and sugarcane). However, the rice paddy system had some SOM pools comparable to those of the forest (Table 2). Again the SOM results indicated that the upland field crop systems were degraded relative to the forest. The paddy system was not degraded as far as SOM

Table 2 Soil Organic Pools and Mineral Nitrogen in Soils under Different Land Uses in Hom Bak Heb Mini-watershed

Land Use	Total Carbon	Total Nitrogen	Microbial Biomass Carbon	Microbial Biomass Nitrogen	Litter (>2 mm size) Carbon	Particulate Organic Matter (1–2 mm) Carbon	Humic Acid Carbon	Mineral Nitrogen
			$g\ kg^{-1}$ soil					$mg\ kg^{-1}$
Forest	5.5 a[1)]	0.30 a	116.1 a	26.6 a	1.13 a	0.40 b	2.93 a	0.75 c
Paddies	4.2 b	0.30 a	78.3 b	29.9 a	1.17 a	1.07 a	2.39 b	2.47 b
Cassava 1	1.2 d	0.05 d	37.2 c	7.1 c	0.20 bc	0.15 b	1.14 d	2.89 b
Cassava 2	1.2 d	0.09 cd	33.5 c	8.0 c	0.15 c	0.17 b	1.25 d	2.34 b
Sugarcane (ratoon)	2.0 c	0.11 bc	78.2 b	17.5 b	0.78 ab	0.14 b	1.82 c	2.71 b
Sugarcane (planted)	4.0 b	0.18 b	75.5 c	16.5 b	0.85 a	0.64 b	1.51 cd	15.37 a

Sources: Adapted from Tangtrakarnpong and Vityakon [2002] and Tangtrakarnpong [2002]

1) Means in the same column followed by similar letters are not significantly different at 95% level of probability (LSD).

indicators revealed. This was likely due to the heavier texture of the paddy soil relative to the upland soils, and the location of the paddies in the low-lying area that was conducive to deposition of materials from the upper-lying parts of the landscape.

Contrary to the SOM results, the mineral N content was lower in the forest than the cultivated fields (Table 2). This shows that the forest system has a higher efficiency of nitrogen cycling than the agricultural systems. Mineral N produced from decomposition of *in situ*-derived organic matter is taken up rapidly by diverse organisms including plants and microorganisms, while little N is input from external sources. On the other hand, the agricultural systems, notably the sugarcane (planted), received higher N input from various external sources, especially from fertilizers. Timing and placement of the fertilizers were likely not precise. This coupled with unsynchronized nutrient requirements of soil microorganisms led to some excess fertilizers remaining in the soil.

These plot-level and partly landscape-level studies suggest that ecosystems with a tree component tend to retard land degradation. The Northeast landscape is tree-studded. There are still trees left at different densities in cultivated fields. Trees in fields are discussed in many research articles, for example Vityakon [2001]; Grandstaff *et al.* [1986]; Watanabe *et al.* [1990], and Takaya and Tomosugi [1972]. This form of indigenous agroforestry has potential for further development aimed at increasing the number of trees in cultivated fields to counter land degradation.

VII Conclusions

VII–1 *Inter-relations among Land-use Changes at Different Scales*

This analysis of land-use change in Northeast Thailand during the past century at four different socio-ecological scales has revealed that changes at all levels have been in a similar direction: the land was transformed from forest to cultivated fields by pioneering farmers. In the earlier subsistence stage land transformation did not lead to dramatic forest loss at any scale. It was only after the region as a whole had entered into the market economy and cash crops were being increasingly cultivated within the communities starting in 1950s that the transformation of forest to cultivated land was rapid.

At the community and landscape levels land transformation began first in the lowlands and worked its way upward to the uplands. The lowland was changed into paddy fields producing rice for subsistence. This pattern was similar in communities situated in both the undulating and the prominently floodplain landforms. The manner of land transformation reflects the influence of biophysical factors, notably terrain, soils and crops to be grown. The lowland areas usually have high fertility soils and flat terrain that facilitates building of large paddy fields. Consequently, irrigated paddy rice was dominant in the region during the first half of the twentieth century [Fukui *et al.* 2000]. This is in agreement with the data at the community level on the prominence of lowland paddy fields that could make use of irrigation water diverted from streams by dams or weirs.

The use of the uplands was also originally for subsistence, such as growing of cotton and sugarcane for home consumption. However, as population increased, paddy fields were expanded into more marginal land on the higher grounds, although these upper paddies were less productive than those in lower-lying areas. During the 1950s, cash crop cultivation in the uplands started. The first crop was kenaf, followed later by cassava and sugarcane. In this regards, the information at different scales, i.e. regional, community and landscape, agrees with each other.

VII–2 *Factors Affecting Land-use Change*

Analysis employing data from both the regional and community levels has shown that at the earlier stage population growth was the leading factor bringing about land-use change from forest to agriculture. Increasing population led to a lower land-to-people ratio and a consequent reduction in land resources available to support livelihoods. Within communities a cultural factor joined forces with population growth in causing out-migration of people to find new land for paddy rice cultivation in a process termed “land pioneering” [Fukui 1993]. At a later stage after the population had grown, the change in the economic orientation of agriculture from subsistence to commercial appears to be the major factor of land-use change at both the regional and the community levels. This economic change was accompanied by many other changes, such as building of infrastructure (good roads, dams and schools etc.), beginning of cash crop growing in the uplands, and the development of agroindustries which required inputs of agricultural products, notably sugar production. In addition, the Northeast was affected more by external factors at both regional and community levels. The external factors came from national and international level. At the regional level, government policies (socio-political factor) favored greater integration of the Northeast into the country as a whole.

VII–3 *Present Conditions of the Land*

The change in land-use from forest to agriculture has brought about changes in land conditions. Degradation characterizes the condition of the upland fields due to erosion, loss of soil nutrients and organic matter. This degradation is associated with the monocultural nature of the upland cultivation that requires applications of fertilizer at higher rates to maintain crop productivity. On the other hand, paddy fields, especially the lower paddies, although under cultivation for longer times than the uplands, still maintain their relatively non-degraded conditions. However, their status depends on their interactions with the uplands since they receive deposits of nutrients and organic materials eroded from the uplands. It is known, for example, that the potassium economy in paddy fields situated in undulating terrain in the Northeast depends in part on K in surface runoff and subsurface water flowing from the uplands [Vityakon 1989]. Thus it can be said that the degradation process in the uplands contributes to the aggradation of the lowlands. It appears that the upland-lowland interactions play important roles in the sustainability of the mini-watershed agroecosystem of the undulating terrain. More landscape level studies are needed to better understand these upland-lowland interactions.

The presence of trees in cultivated fields at the plot scale, and as patches of remnants of forest interspersed with cultivated fields at the landscape scale, is another feature of the present land condition. This feature gives the cultivated fields and the landscape less of a monocultural appearance. These tree resources are consciously maintained by farming households and communities reflecting farmer indigenous knowledge [Vityakon 1993]. These trees serve farmers in various ways in their livelihoods [Grandstaff *et al*. 1986] as well as playing important ecological roles including land conservation [Vityakon 2001].

VII–4 *Implications and Recommendations*

Land degradation is the result of the land-use change occurring in the past century. However, degradation has not occurred equally in various land-use types and it is more severe in the uplands. In the past, when population density was low and unused land was still abundant, people could move to the frontier to clear new land so agriculture was extensive. However, the present trend in agricultural land use in the region is toward greater intensification as no more new land is available. In addition, maintaining productivity requires higher inputs. The land users are now faced with the problem of finding ways to keep the agroecosystem productive and sustainable. Reversion to polycultural agricultural systems, especially those with a tree component that mimic the natural systems is one possible solution. At the same time, a recommendation can be made about development of greater self-reliance of the sort that characterized the subsistence economy. This would reduce the need to produce such large quantities of cash crops in the uplands. Rather than relying to such a large extent on external inputs that must be purchased for cash as they do now, farmers would strive to meet a greater share of their consumption needs on their own farms. These two approaches are closely linked: polyculture tends to lead to ecological sustainability, while self-reliance is associated with sustainability in the socio-economic sense. In fact, the Northeast farm households have always remained subsistence and self-reliant with respect to their rice production. There has been some movement in the direction of polyculture and self-reliance already as the result of the promotion of integrated agriculture, (i.e. agricultural systems that have various kinds of interacting agricultural practices in a single farm. For example a farm can have fish raising in rice paddies plus farm pond for irrigation and fish raising plus poultry raising in pens situated over the farm ponds to enable the poultry droppings to feed the fish and plus fruit trees and multipurpose trees growing in paddy bunds and upland fields), and tree integration into farming systems. Both government agencies and NGOs have lately been promoting increasing tree resources in rural areas. Leading farmers (so-called indigenous intellectual farmers) in the Northeast have formed several networks to promote integrated farming and reduce dependency on commercial agriculture. Government agencies, notably the Royal Forest Department (RFD), have lately promoted integration of trees into cultivated fields and community forestry by organizing farmer training and providing materials, such as seedlings. A most influential advocate of integrated farming and lesser dependency on commercial economy is the Thai King himself. He has suggested to his people in recent years that the nation should seek to keep one-forth of the economy, at all system hierarchical levels or scales, as subsistence-oriented while the rest can be integrated into the commercial (market) economy. By this he meant that, the one-quarter of the economy which does not rely on external factors can act as a buffer against changes in the influential external forces. The other 75% of the economy can function in propelling further growth of the cash economy—the dominant system in the modern world.

Land-use change in the past century has transformed the land cover of the Northeast from forest to agricultural fields, notably monocultural fields. Commercialization of the economy was the major factor that brought about this change, which, unfortunately, has been accompanied by serious land degradation. Reversing this trend is an urgent priority if development in the Northeast is to be sustainable. Replacement of monocultural agricultural systems with polycultural systems, especially those systems with tree components, and the adoption of a certain degree of subsistence orientation in the economy can help the Northeast to achieve ecological, economic and social sustainability in the new century.

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Nutrient Balances and Sustainability of Sugarcane Fields in a Mini-Watershed Agroecosystem of Northeast Thailand

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Abstract

Large areas of undulating terrain in Northeast Thailand are dominated by farming systems based on rainfed upland crops and lowland rice. Evidence of a substantial decline in land productivity from current land uses and management points out the need for a more detailed assessment on land-use sustainability of the region. The present study evaluated nutrient balances of different types of sugarcane fields as an indicator of land-use sustainability. The crop is currently the most widely grown field crop in the region, and its production practices involve high fertilizer inputs and considerable soil disturbances. Kham Muang village in Khon Kaen province was selected as a study site. Four types of sugarcane subsystems were recognized based on their differences in nutrient input and output parameters. These included combinations of two rates (high and low) of fertilizers and two practices of field burning prior to harvesting (burned and not burned). Sources of nutrient inputs and outputs were identified for the individual subsystems. Amounts of major nutrients (N, P and K) were determined for the individual sources, based primarily on actual field measurements in farmers' fields in Kham Muang and adjacent villages and in a mini-watershed in Kham Muang village. Nutrient balances were then calculated for the full three-year cycle of the individual subsystems and at three yield levels (high, moderate and low). The results showed that N balances were mostly positive but P and K balances were negative for all subsystems. Positive balances of N were high at the high fertilizer rate and low yield level, declined at the low fertilizer rate and higher yield levels, and became negative when the field was burned. Negative P and K balances increased as yield level increased and when the low rate of fertilizer was applied. Field burning caused significant losses for all three nutrients, making negative balances even higher for P and K in burned field; the amounts were quite substantial in all subsystems. Excess N is likely to be lost through water flow, but continuation of current practices can cause P and K depletion in the long run. Measures to adjust the balances of these two nutrients are needed to improve land-use sustainability of sugarcane production in the region.

Keywords: nutrient balance, nutrient cycling, nutrient budget, sugarcane, agroecosystem, land degradation, land-use sustainability, Northeast Thailand

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I Introduction

Agricultural systems in Northeast Thailand have been developed on rather marginal poor sandy soils of the undulating terrain. The development of agricultural land use was through forest clearing for production of rice and commercial upland crops [Vityakon 2002; Vityakon *et al*. 2004]. The gently undulating terrain dominates the region's landscape forming a "mini-watershed" agroecosystem in which paddy rice occupies the lowlands and various field crops as well as remnants of dipterocarp forest are in the uplands. The dominant field crop has changed from monoculture of kenaf to cassava, and most recently to sugarcane. Continuous cultivation of these crops has resulted in a substantial decline in land productivity as indicated by declining crop yields and an increasing dependency on chemical fertilizers to obtain satisfactory yield levels [Limpinuntana 1988]. Previous studies also have shown a general decline in fertility of upland soils as indicated by a decline in soil nutrients and soil organic matter [Limpinuntana *et al*. 2000]. The situation creates skepticism regarding land-use sustainability of the region. A more detailed assessment of land-use sustainability under current practices is needed. Currently, sugarcane is the most widely grown upland crop in the region, occupying both the upland and the upper lowland of the undulating terrain. Its cultural practices involve high fertilizer inputs and considerable soil disturbances [Wongwiwatchai and Paisancharoen 2001]. Some farmers also burn the cane fields prior to harvesting to facilitate the stem-cutting operation [Wongchantra 2002], causing a significant loss of certain nutrients. Land-use sustainability of the system is unclear and warrants an in-depth analysis. The system is of more general interest because it represents a relatively high-input extensive commercial cash crop production in a rather low-productivity sandy soil in a semi-arid tropic environment.

Analysis of nutrient balances is a simple and useful methodology to assess the sustainability of agricultural land-use systems. The method has been used as a tool for assessing the sustainability of many land-use systems in various parts of the world, including Africa and Europe [Janssen 1999; Oenema and Heinen 1999; Smaling *et al*. 1999], Asia [Manaligod and Cuevas 1998; Patanothai 1998; Polthanee *et al*. 1998; Vien 1998] and America [Jordan 1985]. In relating nutrient balance to long-term sustainability of land productivity, the basic assumption is that a negative balance of any nutrient would indicate a loss of the nutrient from the system. Long-term continuation of such a situation will result in a degradation of land quality and consequently a decline in productivity and sustainability. A high positive balance of certain nutrients may also adversely affect land-use sustainability if these nutrients are accumulated to a level that could create a plant nutrient imbalance or toxicity or even excess export from the system [Patanothai 1998]. Our previous study on nutrient balances of sugarcane fields in Northeast Thailand with different field positions, fertilizer rates and field burning practices [Polthanee *et al*. 1998] indicated positive balances for all three major nutrients (N, P and K) in all types of fields. However, in that study, the analysis was based mainly on secondary data. The present study also investigated nutrient balances of different types of sugarcane fields, but the analysis was based primarily on primary data obtained from field measurements in a study site representing a mini-watershed agroecosystem in Northeast Thailand. The objectives were (1) to determine the amount of nutrients in various sources of inputs and outputs for different types of sugarcane fields, and (2) to determine the balances of major nutrients in these fields as an indicator of land-use sustainability.

II Methodology

II–1 *The Study Site*

The site chosen for this study was Kham Muang village in Khon Kaen province in Northeast Thailand (latitude 16˚ 48'–16˚ 49' north and longitude 102˚ 52'–102˚ 53' east), approximately 45 km north of Khon Kaen city. The general landscape of the area is undulating terrain, typical of a mini-watershed agroecosystem in the region. Soils are coarse textures (loamy sand to sandy loam) classified as Oxic Quartzipsamment. The rainy season is from April to October, with annual rainfall approximately 1,200 mm. Crops grown in the area are sugarcane, cassava and rice, with sugarcane and cassava occupying the upland areas and rice occupying the lowland areas.

II–2 *Determination of Nutrient Inputs and Outputs and Field Types*

To determine sources of nutrient inputs and outputs, field surveys and farmer interviews were conducted in Kham Muang and neighbouring villages. A Rapid Rural Appraisal (RRA) was used in gathering information on current practices for sugarcane production in the area and variations among farmers in production practices. Information obtained from the interviews included variety grown, planting date and method, kind and rate of fertilizer applied, time and method of weeding, harvesting date and method, and plant parts removed from and retained in the field.

Major sources of nutrient input into a sugarcane field identified were planting materials, chemical fertilizers, rainfall, in-coming eroded sediments and run-in water from adjacent upper fields, and run-in subsurface water. Major nutrient outflows were harvested canes, losses through field burning before harvesting, out-going eroded sediments and run-off water to a lower field, leaching, and run-out subsurface water (Fig. 1). No manure was normally applied to the crop, and not many leguminous weeds were found, thus, manure and nitrogen fixation were omitted from the input sources. Other gaseous losses were considered minor and were also omitted. Weeds were left in the field after weeding, and sugarcane leaf litter and leaves were retained in the field if not burned. These were considered recycled plant parts and were not included in the nutrient balance analysis.

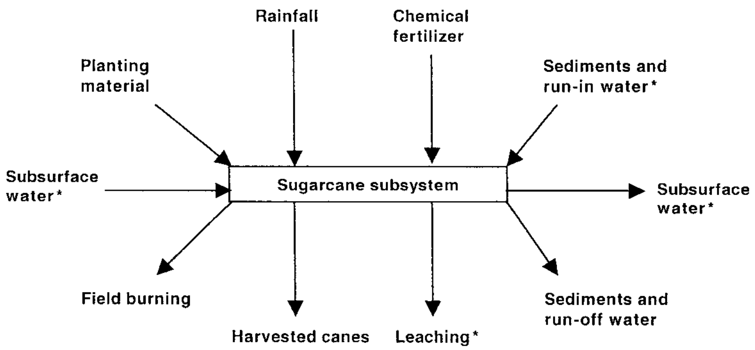

Fig. 1 Major Nutrient Flows for a Planted-sugarcane Field in a Mini-watershed in Northeast Thailand

*not measured

In Northeast Thailand, a cycle of sugarcane planting consists of three years, corresponding to a planted crop, a ratoon crop and a fallow period. The cycle begins with the planted crop, which is normally planted at the end of the rainy season in October to November and harvested about 14–16 months later in December to March, the operating season of sugar factories. The field is then left for ratooning, and the ratoon crop is harvested in the following December to March. After that the field is generally left fallow throughout the rainy season until the next planting in the following October to November. Some plowing are also done during the rainy season as a part of field preparation for end-of-season planting. In this study, nutrient balance analyses were done for the full cycle (three years) of sugarcane planting system. Sources of nutrient inflows and outflows indicated in Fig. 1 were applicable to the planted crop, and also to the ratoon crop but with the omission of planting material. As sub-surface flows and in-coming eroded sediments and water were not measured, the only nutrient inflow during the fallow period was rainfall and the nutrient outflows were only out-going sediments and run-off water.

Variations among fields for sources of nutrient flows were found to reflect three main factors. Fields located at different positions along the sloping landscape would differ in eroded sediments and water coming in and going out of the fields. Farmers who were quota holders from a sugar factory applied the 15–15–15 fertilizers at a high rate (625 kg/ha) as they received credits for production inputs from the factory. Non-quota holders normally applied the same kind of fertilizer but at a lower rate (312.5 kg/ha). Some farmers burned their sugarcane fields prior to harvesting to facilitate the harvesting operation but others did not. Nutrient losses from burning would be different between burned and unburned fields. In the classification of field types (subsystems) for nutrient balance analysis, however, field position was not included in the criteria as it was difficult to determine the amounts of deposition of in-coming eroded sediments and water before leaving the field. Based on differences in fertilizer application and field burning practices, four field types (subsystems) of sugarcane were recognized. These included combinations of two rates (high and low) of fertilizer application and two practices of field burning prior to harvesting (burned and not burned). Subsequent quantity determinations of nutrient inflows and outflows were done for each sugarcane subsystem.

II–3 *Quantification of Nutrient Inflows and Outflows*

Amounts of major nutrients (N, P and K) for various sources of nutrient inputs and outputs for the individual sugarcane subsystems were mainly done by actual field measurements in farmers' fields in Kham Muang and two adjacent villages and in a mini-watershed in Kham Muang village. The selected mini-watershed covers an area of 14 ha. The topography is gently undulating with an average slope of 2.8% and elevation ranging from 190 to 208 m above mean sea level. The soils are Oxic Quartzipsamment with loamy sand to sandy loam texture. Land uses are typical for the area, i.e. forest on top slope, field crops (sugarcane and cassava) in upper and lower upland fields and in upper paddies on lower slope, while rice is grown in lower paddies on the foot slope. An automatic weather meter with data logger was installed at the site, and run-off plots were set up at key positions to measure sediments and run-off water from different land uses.

In this study, the inputs of nutrients to a sugarcane subsystem that were included in the nutrient balance analysis were rainfall, chemical fertilizers and planting material. The outputs were harvested canes, loss through burning, outgoing sediments and run-off water. Flows of nutrients in and out of the field by subsurface water and leaching loss, though considered important, were not included in the analysis as their measurement was rather difficult. Procedures for determining mineral nutrients (N, P and K) in different sources of inputs and outputs that were taken into account in this study are as follows:

1) *Rainfall*

Amounts of daily rainfall from 1991 to 2002 were recorded by an automatic weather meter (Unidata Australia with Starlog model 6301B) installed at the study mini-watershed. Total rainfall for the planted crop, the ratoon crop and the fallow periods was determined in accordance with the corresponding periods for sediments and run-off water determination (see more details in later section). N, P and K contents of rain water from a previous study [Polthanee *et al.* 1998] were used in the calculation of amounts of N, P and K brought in by rainfall for the individual periods.

2) *Chemical Fertilizers*

The kind and amounts of chemical fertilizers applied to sugarcane fields were obtained by interviewing sugarcane growers in the study village and two adjacent villages. Nutrient contents of the applied fertilizer (15–15–15) were used in calculating the amounts of N, P and K brought in by chemical fertilizer at a high (625 kg/ha) and a low (312.5 kg/ha) rate.

3) *Planting Materials*

In determining nutrient input from planting material, a sample of 10 canes was taken from a farmer's field which was being planted. Individual canes were measured for length and fresh weight. They were then oven-dried to obtain dry weight, and means were calculated for length and dry weight of a cane. Sugarcane is normally planted in furrows spaced 1 m apart, and planted canes are laid linearly in the furrows with overlapping ends of the two consecutive canes. Lengths of overlapping ends of planted canes were measured in 4 fields, each with 10 spots. The average values for length of overlapping end and for length and dry weight per cane were used in computing the number of canes used for planting a hectare and its corresponding dry weight. Average nutrient contents of harvested canes obtained from yield measurements in 14 fields (described below) were used in determining the amounts of N, P and K brought in by planting material.

4) *Harvested Canes*

Harvested cane yields were measured in 14 farmers' fields in Kham Muang and two adjacent villages in 1999–2000. Crop cuttings were done in 5 quadrates of 2×2 m^2 in 2 fields and in 4 quadrates in 12 fields. In a quadrate, all sugarcane stems were cut at soil surface and leaf litter was collected from the ground. Leaves (including leaf litter and tops) were separated from stalks, and the two parts were separately weighed. Samples were taken for oven drying to determine their moisture contents, one form each quadrate for leaves and a composite sample from all quadrates for stalks. Dry weights per hectare were then calculated for stalks and leaves. After drying, a composite sample was taken from each part and analyzed for N, P and K contents. Nutrient content analyses were done for 13 fields, of which 9 were burned fields and 4 were not burned fields. In nutrient balance analyses, three yield levels were set as scenarios. Averages for nutrient contents of stalks over all 13 fields were used in determining the outflow amounts of N, P and K through harvested canes at different yield levels. Averages for nutrient contents of leaves were calculated separately for burned and not-burned fields. These were used in determining the amounts of nutrient losses through field burning before harvesting and nutrient recycled through leaves remaining in the field.

5) *Losses of Nutrients from Field Burning*

Losses of nutrients from field burning were determined as the differences between total nutrients in all leaves and nutrients remained in unburned leaves and ash. Total dry weight of leaves at a certain yield level was calculated from the corresponding cane dry weights using a percentage of dry leaf weight to dry cane weight derived from means for cane and leaf yields of 4 fields that were not burned. Among the 14 fields harvested for yield determination, 2 were actually the same field but a part was burned and the other part was not. The 2 parts were harvested separately and were considered as 2 fields. Percentage of leaf weight loss from field burning was determined from average dry weights of leaves of these 2 fields. Percentage of leaf weight remaining as ash after burning was taken from a previous study [*ibid.*] in which leaf samples were actually burned and weights of ash were measured. Nutrient contents of ash from the same study were also used in the calculation of nutrients retained in the ash from field burning.

6) *Sediments Outflow and Run-off Water*

Five erosion plots were constructed at different positions along the toposequence in the mini-watershed. One was in the forest, two were in upper and lower cassava fields and two were in sugarcane fields. Each plot consisted of 5 ridges and 4 furrows, with a sediment tank setting up at the lower end. The amounts of erosion materials were determined by measuring the height of liquid in the sediment tank in the morning following each rainstorm. Liquid in the tank was also sampled for separation of sediments and run-off water and subsequently analyzed for their N, P and K contents. These were used in calculating amounts per hectare of nutrient losses through sediments and run-off water of individual erosion plots. Data were collected from August 1999 to December 2002, and the details are described in Vityakon and Trelo-ges [2003].

In one erosion plot (the middle upland plot), the crop in 1999 was ratoon sugarcane, followed by a fallow period in 2000, then by cassava that was planted in October 2000 and harvested in September 2001. Afterward, sugarcane was planted in October 2001 and harvested in early-2003. Data collected from this plot were used in estimating the outflows of nutrients through sediments and run-off water in the different periods in the cycle of sugarcane planting system. Data from the year 2002 were used to represent nutrient losses from sediments and run-off water for the planted crop period, and those from the year 2000 were used for the fallow period. As data for ratoon sugarcane in 1999 were available only from August, they were combined with data from January–July 2000 when the field was under cassava to get the estimate of nutrient losses through sediments and run-off water for the entire ratoon crop period.

II–4 *Chemical Analysis of Soil, Plant and Water Samples*

For sediment samples, total N was determined by micro Kjeldahl method, and total P and K were obtained by nitric perchloric acid digestion. P was determined by molybdenum blue method (Murphy and Riley), while K was determined by flame photometric method.

For plant samples, total N was determined by micro Kjeldahl method, and total P and K were obtained by dry ashing method. P and K were determined in the same way as those for sediment samples.

For water samples, total N was determined by sulfuric acid digestion of micro Kjeldahl method. For P and K determination, water samples were digested by mixture of sulfuric acid and nitric acid, and P was determined by the molybdenum blue method (Murphy and Riley) and soluble K was measured by flame photometer.

II–5 *Nutrient Balance Analyses*

Nutrient balance analyses were done for all four sugarcane subsystems, i.e. high fertilizer rate–field not burned, high fertilizer rate–field burned, low fertilizer rate–field not burned and low fertilizer rate–field burned. For each subsystem, analyses were done for the full cycle (three years) of sugarcane planting system and at three yield levels (high, medium and low, equal to 40, 30 and 15 tons/ha of dry cane or 129.6, 97.2 and 48.6 tons/ha of fresh-cane).

III Results and Discussion

Dry cane yields of the 14 farmers' fields harvested ranged from 13.9 to 41.0 tons/ha with an average of 28.4 tons/ha (Table 1). Yield differences could not be discerned between fields receiving high and low rates of fertilizer, or between fields with different burning practices, as well as between planted crop and ratoon crop. For example, fields with high rate of fertilizer had cane yields ranging from 13.9 to 41.0 tons/ha while fields with low fertilizer rate gave yields from 28.4 to 40.7 tons/ha. These could be accounted for by confounding effects of the above three and other factors as the numbers of fields for different categories were unequal and these fields were scattered in different places around the three study villages. These results indicated a naturally high variation in sugarcane yield among farmers' fields

Table 1 Means for Dry Cane and Dry Stubble Yields in Farmers' Fields in 1999–2000 at Ban Kam Moung, Khon Kaen, Thailand

Field no.	Farmer's Name	Fertilizer Rate[1]	Field Burning	Crop Year	Dry Cane Yield (kg/ha)[2]	Dry Stubble[3] (kg/ha)[2]	Dry Stubble[3] (%)[4]
1	Mr. Boonlert	Low	Yes	Ratoon	40,138	3,996	9.93
2	Mr. Boonlert	Low	No	Ratoon	32,209	8,335	25.62
3	Mr. Sanit	High	Yes	Ratoon	40,956	2,849	7.16
4	Mr. Sompong	High	Yes	Ratoon	24,613	2,845	11.70
5	Mr. No	Low	No	Ratoon	28,408	8,361	28.90
6	Mr. Boonmee	High	Yes	Planted	23,182	1,966	8.64
7	Mr. Sak	High	Yes	Planted	23,253	–	–
8	Mr. Paitoon	High	Yes	Planted	34,229	–	–
9	NA	NA	Yes	NA	23,075	–	–
10	Mr. Sawai	NA	Yes	NA	26,606	–	–
11	Mr. Boama	High	No	Planted	13,922	–	–
12	Mr. Somkid	Low	Yes	Planted	40,734	–	–
13	Mr. Tongsan	NA	No	Ratoon	31,453	6,569	20.94
14	Mr. Tawatchai	NA	No	Ratoon	15,131	5,493	35.60
	Overall mean				28,422	5,052	18.56
	Mean		Yes				9.36
	Mean		No				27.76

[1] Low = 312.5 kg/ha and high = 625 kg/ha of 15–15–15 compound fertilizer.
[2] Means from 5 replicates for Field nos. 1 and 2, others were from 4 replicates.
[3] Including leaves and tops; for burned fields, these were remaining unburned parts.
[4] Percent of dry cane yield.

Table 2 Nutrient Input from Rainfall and Nutrient Losses through Sediments and Run-off Water in the three-year Cycle of Sugarcane Planting in Northeast Thailand

Category	Amount	Nutrient (kg/ha)		
		N	P	K
Year 1 (Planted crop)				
Rainfall	1,312 mm	2.95	1.61	2.14
Sediments	16,800 kg/ha	3.30	1.24	2.21
Run-off water	253.9 mm	0.23	5.31	17.90
Year 2 (Ratoon crop)				
Rainfall	1,203.8 mm	2.71	1.48	1.96
Sediments	13,570 kg/ha	2.71	0.95	1.76
Run-off water	184.0 mm	0.17	3.85	12.97
Year 3 (Fallow)				
Rainfall	1,246 mm	2.80	1.53	2.03
Sediments	20,420 kg/ha	8.17	1.15	3.27
Run-off water	116.4 mm	0.66	1.87	30.13
Total 3 years				
Rainfall		8.46	4.62	6.13
Sediments and runoff		15.24	14.37	68.25

even with the same management practice. For this reason, three yield levels within the range in this study were used as scenarios in the analysis of each sugarcane subsystem. The high, moderate and low yield levels were set at 40, 30 and 15 tons/ha of dry-cane yields (equal to 129.6, 97.2 and 48.6 tons/ha of fresh-cane yields), respectively. Average yield of sugarcane in Northeast Thailand in 2001–02 was 18.1 tons/ha dry weight or 58.6 tons/ha fresh weight [OAE 2003].

The four subsystems analyzed included high fertilizer rate-field not burned, high fertilizer rate–field burned, low fertilizer rate–field not burned and low fertilizer rate–field burned. Each was analyzed for the full three-year cycle covering the planted crop, the ratoon crop and the fallow period, and with three yield levels (high, moderate and low). The same amounts of nutrient inflows by rainfall and planting material were used for all subsystems at all yield levels, as were nutrient outflows by sediments and run-off water. Table 2 shows the amounts of N, P and K brought in by rainfall and going out by sediments and run-off water in the individual years of the planting cycle. Their nutrient concentrations are given in Table 3. Nutrients brought in by rainfall were small and insignificant, the amount over the 3-year period being 8.46, 4.62 and 6.13 kg/ha for N, P and K, respectively. Although the amounts of out-going sediments and run-off water were quite considerable, totaling 50.7 tons/ha for sediments and 554.3 mm for run-off water, the amount of nutrient losses through these two sources were not great. Combined amounts from both sources over the three-year period were 15.24, 14.37 and 68.25 kg/ha for N, P and K, respectively. This was because soils at the study site were quite poor in fertility, as shown by low nutrient concentrations for both sediments and run-off water (Table 3).

As expected, soil erosion was lower in the ratoon-crop year than in the planted-crop year due to better ground cover (Table 2). Soil erosion was more serious during the fallow period

Table 3 Nutrient Concentration of Input and Output Components

Component	Nutrient			Source
	N	P	K	
Rainfall (ppm)	0.225	0.123	0.163	A previous study[1]
15–15–15 fertilizer (%)	15.000	6.546	12.450	
Planting material (%)	0.133	0.377	0.328	Means of 13 fields
Dry cane (%)	0.133	0.377	0.328	Means of 13 fields
Dry leaves (%)	0.436	0.573	1.024	Means of 3 fields
Dry unburned leaves (%)	0.582	0.824	0.961	Means of 7 fields
Leaf ash (%)	0.000	0.110	0.240	A previous study[1]
Sediments, years 1 and 2 (%)	0.020	0.007	0.013	Yearly average[2]
Sediments, year 3 (%)	0.040	0.006	0.016	Yearly average[2]
Run-off water, years 1 and 2 (ppm)	0.091	2.091	7.050	Yearly average[2]
Run-off water, year 3 (ppm)	0.567	1.607	25.885	Yearly average[2]

[1] Unpublished data from our earlier study [Polthanee *et al*. 1998].
[2] Concentrations at different periods in the season were used in the calculation.

as there were soil disturbances by plowing and less ground cover during the period of heavy rainfall. A much higher K concentration in run-off water during the fallow period than in the cropping period (Table 3) also made K loss through run-off water during the fallow period substantially higher. The amounts of sediments and run-off water for the ratoon-crop year might have been overestimated as the amounts for the early part of the season were taken from the period under a cassava crop which probably had less ground cover than ratoon sugarcane. However, with such low nutrient concentrations of both sediments and run-off water, this should not make much difference in terms of nutrient losses.

In this study, the run-in water and sediments from a higher field was not taken into account. However, the erosion plot in which the data were collected had a closed upper end. The amounts obtained would represent the out-going sediments and run-off water for the field with no erosion inflow. These amounts also should not be much different from the balances between the inflows and outflows if there were run-in water and sediments (upper end of the plot opened). In such a case, the amounts of run-out water and sediments should have been higher than those obtained in this study.

Losses of nutrients from field burning before harvesting are presented in Table 4. Significant losses were shown for all three nutrients, particularly at the high yield level. K losses were much greater than those of N and P as leaves had higher K content than N and P (Table 3). Losses from burning at the low yield level were 7.87, 9.45 and 15.05 kg/ha of N, P and K, respectively, and increased to 21.00, 25.21 and 40.14 kg/ha of N, P and K at the high yield level.

Quite considerable amounts of nutrients, particularly K, were recycled back to the field when the field was not burned (Table 4). At the high yield level, recycled nutrients amounted to 51.86 kg/ha for N, 68.84 kg/ha for P and 97.27 kg/ha for K. Even when the field was burned, a large proportion of leaves and tops were unburned, retaining more than half of their nutrients in the field. However, the losses also were considerable, and no field burn-

Table 4 Nutrient Losses from Field Burning before Harvesting Sugarcane and Nutrients Recycled from Leaves at Three Yield Levels

Category	Amount (kg/ha)		
	N	P	K
Loss from burning			
High yield level (40 tons/ha)	21.00	25.21	40.14
Moderate yield level (30 tons/ha)	15.75	18.91	30.10
Low yield level (15 tons/ha)	7.87	9.45	15.05
Recycled nutrients			
Field not burned			
High yield level (40 tons/ha)	51.86	68.84	97.27
Moderate yield level (30 tons/ha)	38.87	51.61	72.92
Low yield level (15 tons/ha)	19.45	25.82	36.48
Field burned before harvesting			
High yield level (40 tons/ha)	30.86	43.63	57.14
Moderate yield level (30 tons/ha)	23.15	32.73	42.85
Low yield level (15 tons/ha)	11.57	16.36	21.43

Table 5a Nutrient Balances for Sugarcane Subsystems in Northeast Thailand: Category I—High Fertilizer Rate, Field not Burned

Component	High Yield Level			Moderate Yield Level			Low Yield Level		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Planted Crop									
Fertilizer (15–15–15)	93.75	40.91	77.81	93.75	40.91	77.81	93.75	40.91	77.81
Rainfall	2.95	1.61	2.14	2.95	1.61	2.14	2.95	1.61	2.14
Planting material	5.19	14.70	12.79	5.19	14.70	12.79	5.19	14.70	12.79
Total input	*101.89*	*57.23*	*92.74*	*101.89*	*57.23*	*92.74*	*101.89*	*57.23*	*92.74*
Sugarcane-stem	53.20	150.80	131.20	39.90	113.10	98.40	19.95	56.55	49.20
Sediments-out	3.30	1.24	2.21	3.30	1.24	2.21	3.30	1.24	2.21
Run-off water	0.23	5.31	17.90	0.23	5.31	17.90	0.23	5.31	17.90
Total output	*56.73*	*157.35*	*151.31*	*43.43*	*119.65*	*118.51*	*23.48*	*63.10*	*69.31*
Balance Year 1	45.16	–100.12	–58.57	58.46	–62.42	–25.77	78.41	–5.87	23.43
Ratoon Crop									
Fertilizer (15–15–15)	93.75	40.91	77.81	93.75	40.91	77.81	93.75	40.91	77.81
Rainfall	2.71	1.48	1.96	2.71	1.48	1.96	2.71	1.48	1.96
Total input	*96.46*	*42.39*	*79.77*	*96.46*	*42.39*	*79.77*	*96.46*	*42.39*	*79.77*
Sugarcane-stem	53.20	150.80	131.20	39.90	113.10	98.40	19.95	56.55	49.20
Sediments-out	2.71	0.95	1.76	2.71	0.95	1.76	2.71	0.95	1.76
Run-off water	0.17	3.85	12.97	0.17	3.85	12.97	0.17	3.85	12.97
Total output	*56.08*	*155.60*	*145.93*	*42.78*	*117.90*	*113.13*	*22.83*	*61.35*	*63.93*
Balance Year 2	40.38	–113.21	–66.16	53.68	–75.51	–33.36	73.63	–18.96	15.84
Fallow									
Rainfall	2.80	1.53	2.03	2.80	1.53	2.03	2.80	1.53	2.03
Sediments-out	8.17	1.15	3.27	8.17	1.15	3.27	8.17	1.15	3.27
Run-off water	0.66	1.87	30.13	0.66	1.87	30.13	0.66	1.87	30.13
Balance Year 3	–6.03	–1.49	–31.37	–6.03	–1.49	–31.37	–6.03	–1.49	–31.37
Balance 3 Years	79.51	–214.81	–156.09	106.11	–139.42	–90.49	146.01	–26.32	7.91

Table 5b Nutrient Balances for Sugarcane Subsystems in Northeast Thailand: Category II—High Fertilizer Rate, Field Burned

Component	High Yield Level			Moderate Yield Level			Low Yield Level		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Planted Crop									
Fertilizer (15–15–15)	93.75	40.91	77.81	93.75	40.91	77.81	93.75	40.91	77.81
Rainfall	2.95	1.61	2.14	2.95	1.61	2.14	2.95	1.61	2.14
Planting material	5.19	14.70	12.79	5.19	14.70	12.79	5.19	14.70	12.79
Total input	*101.89*	*57.23*	*92.74*	*101.89*	*57.23*	*92.74*	*101.89*	*57.23*	*92.74*
Sugarcane-stem	53.20	150.80	131.20	39.90	113.10	98.40	19.95	56.55	49.20
Loss from burning	21.00	25.21	40.14	15.75	18.91	30.10	7.87	9.45	15.05
Sediments-out	3.30	1.24	2.21	3.30	1.24	2.21	3.30	1.24	2.21
Run-off water	0.23	5.31	17.90	0.23	5.31	17.90	0.23	5.31	17.90
Total output	*77.73*	*182.56*	*191.45*	*59.18*	*138.56*	*148.61*	*31.35*	*72.55*	*84.36*
Balance Year 1	24.16	–125.33	–98.71	42.71	–81.33	–55.87	70.54	–15.32	8.38
Ratoon Crop									
Fertilizer (15–15–15)	93.75	40.91	77.81	93.75	40.91	77.81	93.75	40.91	77.81
Rainfall	2.71	1.48	1.96	2.71	1.48	1.96	2.71	1.48	1.96
Total input	*96.46*	*42.39*	*79.77*	*96.46*	*42.39*	*79.77*	*96.46*	*42.39*	*79.77*
Sugarcane-stem	53.20	150.80	131.20	39.90	113.10	98.40	19.95	56.55	49.20
Loss from burning	21.00	25.21	40.14	15.75	18.91	30.10	7.87	9.45	15.05
Sediments-out	2.71	0.95	1.76	2.71	0.95	1.76	2.71	0.95	1.76
Run-off water	0.17	3.85	12.97	0.17	3.85	12.97	0.17	3.85	12.97
Total output	*77.08*	*180.81*	*186.07*	*58.53*	*136.81*	*143.23*	*30.70*	*70.80*	*78.98*
Balance Year 2	19.38	–138.42	–106.30	37.93	–94.42	–63.46	65.76	–28.41	0.79
Fallow									
Rainfall	2.80	1.53	2.03	2.80	1.53	2.03	2.80	1.53	2.03
Sediments-out	8.17	1.15	3.27	8.17	1.15	3.27	8.17	1.15	3.27
Run-off water	0.66	1.87	30.13	0.66	1.87	30.13	0.66	1.87	30.13
Balance Year 3	–6.03	–1.49	–31.37	–6.03	–1.49	–31.37	–6.03	–1.49	–31.37
Balance 3 Years	37.51	–265.24	–236.37	74.61	–177.24	–150.69	130.27	–45.22	–22.19

Table 5c Nutrient Balances for Sugarcane Subsystems in Northeast Thailand: Category III—Low Fertilizer Rate, Field not Burned

Component	High Yield Level			Moderate Yield Level			Low Yield Level		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Planted Crop									
Fertilizer (15–15–15)	46.88	20.46	38.91	46.88	20.46	38.91	46.88	20.46	38.91
Rainfall	2.95	1.61	2.14	2.95	1.61	2.14	2.95	1.61	2.14
Planting material	5.19	14.70	12.79	5.19	14.70	12.79	5.19	14.70	12.79
Total input	*55.01*	*36.77*	*53.84*	*55.01*	*36.77*	*53.84*	*55.01*	*36.77*	*53.84*
Sugarcane-stem	53.20	150.80	131.20	39.90	113.10	98.40	19.95	56.55	49.20
Sediments-out	3.30	1.24	2.21	3.30	1.24	2.21	3.30	1.24	2.21
Run-off water	0.23	5.31	17.90	0.23	5.31	17.90	0.23	5.31	17.90
Total output	*56.73*	*157.35*	*151.31*	*43.43*	*119.65*	*118.51*	*23.48*	*63.10*	*69.31*
Balance Year 1	–1.72	–120.58	–97.47	11.58	–82.88	–64.67	31.53	–26.33	–15.47
Ratoon Crop									
Fertilizer (15–15–15)	46.88	20.46	38.91	46.88	20.46	38.91	46.88	20.46	38.91
Rainfall	2.71	1.48	1.96	2.71	1.48	1.96	2.71	1.48	1.96

Table 5c—Continued

Component	High Yield Level			Moderate Yield Level			Low Yield Level		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Total input	*49.59*	*21.94*	*40.87*	*49.59*	*21.94*	*40.87*	*49.59*	*21.94*	*40.87*
Sugarcane-stem	53.20	150.80	131.20	39.90	113.10	98.40	19.95	56.55	49.20
Sediments-out	2.71	0.95	1.76	2.71	0.95	1.76	2.71	0.95	1.76
Run-off water	0.17	3.85	12.97	0.17	3.85	12.97	0.17	3.8	12.97
Total output	*56.08*	*155.60*	*145.93*	*42.78*	*117.90*	*113.13*	*22.83*	*61.35*	*63.93*
Balance Year 2	–6.50	–133.66	–105.06	6.81	–95.96	–72.26	26.76	–39.41	–23.06
Fallow									
Rainfall	2.80	1.53	2.03	2.80	1.53	2.03	2.80	1.53	2.03
Sediments-out	8.17	1.15	3.27	8.17	1.15	3.27	8.17	1.15	3.27
Run-off water	0.66	1.87	30.13	0.66	1.87	30.13	0.66	1.87	30.13
Balance Year 3	–6.03	–1.49	–31.37	–6.03	–1.49	–31.37	–6.03	–1.49	–31.37
Balance 3 Years	–14.24	–255.73	–233.90	12.36	–180.33	–168.30	52.26	–67.23	–69.90

Table 5d Nutrient Balances for Sugarcane Subsystems in Northeast Thailand: Category IV—Low Fertilizer Rate, Field Burned

Component	High Yield Level			Moderate Yield Level			Low Yield Level		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Planted Crop									
Fertilizer (15–15–15)	46.88	20.46	38.91	46.88	20.46	38.91	46.88	20.46	38.91
Rainfall	2.95	1.61	2.14	2.95	1.61	2.14	2.95	1.61	2.14
Planting material	5.19	14.70	12.79	5.19	14.70	12.79	5.19	14.70	12.79
Total input	*55.01*	*36.77*	*53.84*	*55.01*	*36.77*	*53.84*	*55.01*	*36.77*	*53.84*
Sugarcane-stem	53.20	150.80	131.20	39.90	113.10	98.40	19.95	56.55	49.20
Loss from burning	21.00	25.21	40.14	15.75	18.91	30.10	7.87	9.45	15.05
Sediments-out	3.30	1.24	2.21	3.30	1.24	2.21	3.30	1.24	2.21
Run-off water	0.23	5.31	17.90	0.23	5.31	17.90	0.23	5.31	17.90
Total output	*77.73*	*182.56*	*191.45*	*59.18*	*138.56*	*148.61*	*31.35*	*72.55*	*84.36*
Balance Year 1	–22.72	–145.79	–137.61	–4.17	–101.79	–94.77	23.66	–35.78	–30.52
Ratoon Crop									
Fertilizer (15–15–15)	46.88	20.46	38.91	46.88	20.46	38.91	46.88	20.46	38.91
Rainfall	2.71	1.48	1.96	2.71	1.48	1.96	2.71	1.48	1.96
Total input	*49.59*	*21.94*	*40.87*	*49.59*	*21.94*	*40.87*	*49.59*	*21.94*	*40.87*
Sugarcane-stem	53.20	150.80	131.20	39.90	113.10	98.40	19.95	56.55	49.20
Loss from burning	21.00	25.21	40.14	15.75	18.91	30.10	7.87	9.45	15.05
Sediments-out	2.71	0.95	1.76	2.71	0.95	1.76	2.71	0.95	1.76
Run-off water	0.17	3.85	12.97	0.17	3.85	12.97	0.17	3.85	12.97
Total output	*77.08*	*180.81*	*186.07*	*58.53*	*136.81*	*143.23*	*30.70*	*70.80*	*78.98*
Balance Year 2	–27.50	–158.87	–145.20	–8.95	–114.87	–102.36	18.89	–48.86	–38.11
Fallow									
Rainfall	2.80	1.53	2.03	2.80	1.53	2.03	2.80	1.53	2.03
Sediments-out	8.17	1.15	3.27	8.17	1.15	3.27	8.17	1.15	3.27
Run-off water	0.66	1.87	30.13	0.66	1.87	30.13	0.66	1.87	30.13
Balance Year 3	–6.03	–1.49	–31.37	–6.03	–1.49	–31.37	–6.03	–1.49	–31.37
Balance 3 Years	–56.24	–306.15	–314.18	–19.14	–218.15	–228.50	36.52	–86.13	–100.00

ing would be superior in term of nutrient management.

Results of nutrient balance analyses for the four sugarcane subsystems are shown in Tables 5a, 5b, 5c and 5d. It was quite evident that fertilizer was the only major source of nutrient input and cane yield was the major source of nutrient output. Burning losses also constituted another main output when the field was burned. In the first year (planted crop), nutrient losses through out-going sediments and run-off water could be sufficiently compensated by the nutrient inflows through rainfall and planting material. However, for the ratoon crop in the second year, there was no planting material and nutrient input from rainfall alone was not sufficient to compensate for the erosion losses. Consequently, a slight deficit in K (11 kg/ha) was observed. Essentially, for the two cropping years, balances of nutrients depended on the amounts brought in by fertilizer and the amount taking out by cane yield plus the losses from burning in case of burned field. For the fallow year, negative balances were shown for all three nutrients, but the amount was significant only for K (–31.37 kg/ha).

Table 6 summarized balances of N, P and K at three yield levels in the different years of the individual sugarcane subsystems. Since balances of all three nutrients were rather small in the third year (fallow period), balances for the first two cropping years largely determined the total balances of all subsystems. At the high fertilizer rate, N balances in the first two years were positive at all yield levels, more so when the field was not burned, but decreased when yield level increased. P balances, on the other hand, were negative at all yield levels, and more negative when the field was burned and when the yield level declined. For K, the balances were negative at high and moderate yield levels, but slightly positive at the low yield level. At the low fertilizer rate, positive balances for N during the first two years were much reduced, and became negative at the low yield level, and even at the moderate yield level when the field was burned. Negative P balances increased at all yield levels and the amounts were considerable even at the low yield level. K balances also increased negatively and became negative at all yield levels.

Balances of nutrients for the full three-year cycle followed the same trend as those of the first two years (Table 6). At the low yield level, N were positive in all subsystems, but the amounts were significant only at the high fertilizer rate (130–146 kg N/ha). P and K were all negative except K was slightly positive at the high fertilizer rate and field not burned. The amounts were significant at the low rate of fertilizer (–67 to –86 kg/ha for P and –70 to –100 kg/ha for K). At the moderate yield level, positive N balances declined, while negative balances for P and K increased to a considerable extent (–139 to –218 kg/ha for P and –90 to –229 kg/ha for K). Positive N balances declined further at the high yield level and became negative at the low fertilizer rate. P and K balances were more negative at the high yield level, and the amounts were quite substantial in all sugarcane subsystems (–215 to –306 kg/ha for P and –156 to –314 kg/ha for K).

The results of this study were somewhat different from those of our previous study [Polthanee *et al.* 1998] in which positive balances were found in all sugarcane subsystems. However, in that study, the analyses were done only for the planted crop year and cane

Table 6 Summary of Nutrient Balances for Sugarcane Subsystems in Northeast Thailand at Three Yield Levels

Category/ Period	N Balance (kg/ha)			P Balance (kg/ha)			K Balance (kg/ha)		
	High Yield	Moderate Yield	Low Yield	High Yield	Moderate Yield	Low Yield	High Yield	Moderate Yield	Low Yield
Category I: High fertilizer rate, field not burned									
Year 1	45.16	58.46	78.41	–100.12	–62.42	–5.87	–58.57	–25.77	23.43
Year 2	40.38	53.68	73.63	–113.21	–75.51	–18.96	–66.16	–33.36	15.84
Year 3	–6.03	–6.03	–6.03	–1.49	–1.49	–1.49	–31.37	–31.37	–31.37
3 Years	79.51	106.11	146.01	–214.81	–139.42	–26.32	–156.09	–90.49	7.91
Category II: High fertilizer rate, field burned									
Year 1	24.16	42.71	70.54	–125.33	–81.33	–15.32	–98.71	–55.87	8.38
Year 2	19.38	37.93	65.76	–138.42	–94.42	–28.41	–106.30	–63.46	0.79
Year 3	–6.03	–6.03	–6.03	–1.49	–1.49	–1.49	–31.37	–31.37	–31.37
3 Years	37.51	74.61	130.27	–265.24	–177.24	–45.22	–236.37	–150.69	–22.19
Category III: Low fertilizer rate, field not burned									
Year 1	–1.72	11.58	31.53	–120.58	–82.88	–26.33	–97.47	–64.67	–15.47
Year 2	–6.50	6.81	26.76	–133.66	–95.96	–39.41	–105.06	–72.26	–23.06
Year 3	–6.03	–6.03	–6.03	–1.49	–1.49	–1.49	–31.37	–31.37	–31.37
3 Years	–14.24	12.36	52.26	–255.73	–180.33	–67.23	–233.90	–168.30	–69.90
Category IV: Low fertilizer rate, field burned									
Year 1	–22.72	–4.17	23.66	–145.79	–101.79	–35.78	–137.61	–94.77	–30.52
Year 2	–27.50	–8.95	18.89	–158.87	–114.87	–48.86	–145.20	–102.36	–38.11
Year 3	–6.03	–6.03	–6.03	–1.49	–1.49	–1.49	–31.37	–31.37	–31.37
3 Years	–56.24	–19.14	36.52	–306.15	–218.15	–86.13	–314.18	–228.50	–100.00

yields were comparable to the low yield level in this study. Nutrient contents of canes were also less than those of this study particularly P and K contents, and losses from sediments and run-off water were not included in the analyses. Since measurements of input and output components in this study were done in more replicates and some also covered a number of fields, data obtained should be more reliable than those of the previous study.

The above results raise some concern about land-use sustainability of the undulating landscapes in the Northeast Thailand. Positive N balance should not be a problem since N is soluble and is likely to be lost through water flow both laterally and vertically. Negative balances for P and K are of considerably more concern, as the amounts were substantial, particularly at moderate to high yield levels. These yield levels were not exceptional since they were obtained from actual measurement in farmers' fields. Continuation of the current practices would certainly threaten the sustainability of land productivity in the long run. Means to adjust the balances of these two nutrients should be sought to sustain the long-term productivity of the land. Nutrient losses through burning could be avoided by giving up the practice of burning the field before harvesting. Fortunately, field burning also causes a reduction in sugar content, and sugar factories are currently buying canes from burned fields at a lower price. This is a good incentive for farmers to give up the field burning practice. Attempts have also been made to grow legumes during the fallow period to replenish nutrients in the soil. Several legumes could be used including grain legumes (particularly peanut), green manure legumes and forage legumes. Rotating sugarcane with other field crops also might better maintain nutrient balances. Fully replenishing the negative balances of nutrients with chemical fertilizers might have to be done if there is no other alternative.

Under existing cultural practices, maintaining nutrient balances in the sugarcane fields are largely dependent on the farmers being able to purchase fertilizer inputs. In the four subsystems of sugarcane production investigated, the major nutrient input was chemical fertilizer while the major nutrient loss is harvested sugarcane stems. Thus, nutrients removed from the soil through yields are replenished by application of chemical fertilizers. A large proportion of sugar produced is exported while chemical fertilizers used in Thailand are imported. This is a case in which significant nutrient flows are occurring across national boundaries. With low crop price and increasing price of chemical fertilizers, it is questionable whether the farmers will earn sufficient income to be able to fully replenish the nutrient removed in the cane with imported chemical fertilizer. This would pose a major threat to land-use sustainability of the sugarcane production system in Northeast Thailand. What is happening in the sugarcane production system in Northeast Thailand might also be occurring in other high input commercial cash crop systems in low fertility soils in the semi-arid tropics.

IV Conclusions

Results of nutrient balance analyses of four sugarcane subsystems in a mini-watershed agroecosystem in Northeast Thailand indicated that land-use sustainability of these subsystems is under a threat from high negative balances of P and K from current practices. In all the subsystems, the major source of nutrient input was chemical fertilizer and that of the output was cane yield. Nutrient losses from field burning before harvesting were also quite considerable, and were an additional significant output for the subsystems with burned field. Although the amounts of eroded sediments and run-off water were substantial, resulting nutrient losses were rather small and could largely be compensated by nutrients brought in by rainfall and planting material. Nutrient balances in all the subsystems were, thus, largely determined by the amounts brought in by fertilizers and the amounts removed by cane yield. At the yield level of 15 tons/ha of dry cane (48.6 tons/ha of fresh cane), negative balances for P and K were low at the high fertilizer rate and would not be much of a problem. However, the amounts became significant when a low rate of fertilizer was used. At yield levels of 30 tons/ha of dry cane (97.2 tons/ha of fresh cane) and above, negative balances for these two nutrients were quite substantial even at the high fertilizer rate. If such a condition continues, P and K would be depleted in the long run, posing a threat to long-term productivity of the land. Means to adjust these balances are needed to improve their land-use sustainability.

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A Nutrient Balance Analysis of the Sustainability of a Composite Swiddening Agroecosystem in Vietnam's Northern Mountain Region

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Abstract

This paper reports some results of the first three years of an on-going research project on nutrient balances in a composite swidden agroecosystem. In a composite swiddening system, households simultaneously cultivate both swidden fields on hill slopes and paddy fields in the valleys. The study is being carried out in Ban Tat, a small settlement of Da Bac Tay ethnic minority people in Hoa Binh Province in Vietnam's Northern Mountain Region. Nutrient inputs and outputs for a swidden field on a hill slope and a wet rice field in the valley below it were recorded and nutrient balances for each subsystem calculated. The swidden had large negative balances for N, P, and K in all years of the experiment whereas in the paddy field only K was in serious deficit. Nutrients lost from the swidden field constituted a major source of inputs into the paddy field. This suggests that the sustainability of wet rice agriculture in the valleys is heavily dependent on interactions with the hill slopes.

At the level of the composite swidden system as a whole, nutrient inputs and outputs were not in balance. Outputs of N exceeded inputs by 159 kg/ha and outputs of K exceeded inputs by 867 kg/ha. Only P showed a positive balance with inputs exceeding outputs by 220 kg/ha. Comparison of the nutrient balances for the swidden and the wet rice field revealed that the negative imbalance of nutrient inputs to outputs was much greater in the swidden field than in the paddy field. Thus, if the farmers at Ban Tat relied exclusively on swiddens to meet their food requirements, their agricultural system would be much less sustainable than it is now. This confirms the main hypothesis of this research that it is the fact that most households simultaneously cultivate both wet rice fields and swiddens that explains the relatively high sustainability of the land use system in Ban Tat.

Keywords: swidden agriculture, nutrient balance, sustainability, Da Bac Tay ethnic group, upland farming system, input-output analysis

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I Introduction

The question of whether swidden agriculture (also called shifting cultivation or slash and burn farming) is a sustainable land use in the mountains of Vietnam continues to be a hotly debated issue. Some anthropologists have asserted that swiddening is a highly sustainable and productive system under traditional conditions of land use. Bui Minh Dao [2000], for example, claims that traditional rotational swiddening in the Central Highlands of Vietnam was highly productive, giving a higher yield per labor hour than wet rice farming, and was also sustainable as long as the ratio of cultivated land to fallow land did not exceed 1 : 10. Thus, when population densities in the mountains were low (<15 persons/km^2) and the need to use land to raise cash crops limited, swidden agriculture represented a very successful adaptation. Everywhere in Vietnam's uplands, however, populations have increased well beyond the carrying capacity of traditional shifting cultivation systems. This trend has been exacerbated by the rapid expansion of the area devoted to growing of cash crops and increasingly strict government regulations that limit farmers' access to remaining areas of forest. Consequently, upland farmers have had to intensify production on their shrinking area of swidden fields and shorten the fallow period to only a few years. This has led in many areas to a loss of forest cover, rapid land degradation and serious yield declines, especially in the Northern Mountain Region (NMR).

In some parts of the NMR, however, ethnic minority farmers employ a system of composite swiddening [Rambo 1998]. This system of land use appears to be more sustainable than pure shifting cultivation systems. Composite swiddening is a unique type of agroecosystem that integrates permanent wet rice fields in the valley bottoms, rotating swidden pilots on the hill slopes, and exploitation of wild resources of the forest into a single household resource system. This system is employed by the Da Bac Tay ethnic minority people of Ban Tat (Tat Hamlet) in Hoa Binh province in the Northwestern Mountains, the study site for the research reported in this paper.

This composite system is able to support higher population densities with less environmental degradation than can pure shifting cultivation. Although the Da Bac Tay people of Ban Tat have engaged in composite swiddening for at least a century, their community retains a high level of forest cover. Between 1954 and 1999, population density increased by more than 7 times, from 10 persons/km^2 to 75 persons/km^2, yet the area covered by forest or regenerating forest vegetation decreased by only 5 percent, from 92 percent to 84 percent of the landscape [Fox *et al*. 2000: 523–525].

Based on initial field research at Ban Tat, Rambo [1998] suggested that composite swiddening was a highly sustainable form of shifting cultivation that, if it could be further improved, could offer a model for use elsewhere in the NMR. In order to experimentally verify this hypothesis and begin developing ways to improve the productivity and sustainability of this system, Hanoi Agricultural University (HAU) initiated a long-term study of nutrient balances in swidden and paddy fields in Ban Tat. Analysis of nutrient balances was seen as offering an operationally feasible method for empirically measuring system sustainability.

The central hypothesis of our research is that *it is the fact that most households simultaneously cultivate both wet rice fields and swiddens that explains the high evident sustainability of composite swiddening in Ban Tat.* The wet rice fields yield approximately half of the grain produced by each household with the swiddens yielding the other half. Thus, the existence of the wet rice fields reduces the pressure to clear new areas of forest or shorten the fallow period of abandoned swidden plots that, in a pure swiddening system, would quickly lead to degradation of vegetation cover and soils. At the same time, crops such as canna and ginger raised in swiddens are sold for cash used to buy rice from the market, thus reducing the need for households to be self-sufficient in grain production. This further reduces the pressure to clear additional large areas of forest for rice cultivation and thus inhibits widespread land degradation.

That the farmers of Ban Tat manage the swidden and wet rice field subsystems in ways that maintain a positive soil nutrient balance in each subsystem is a second hypothesis of our research. In the case of the wet rice fields, nutrient balance is probably maintained over the course of each annual cropping cycle with nutrient inputs equal to nutrient outputs for each crop. In the case of the swiddens, the question is much more complex and must be studied over the duration of the entire multi-year cycle of cultivation and fallowing. Our study is designed to measure nutrient balances of each of the two key subsystems over the full rotational cycle of cultivation. In the present paper only data collected during the first three years are analyzed so that no conclusions can be reached about the validity of this hypothesis.

The existence of strong positive functional linkages between the swiddens and wet rice field subsystems also appears to contribute to the sustainability of the land use system as a whole. Nutrients carried into the paddy fields by run-off water from the hill slope swiddens may increase yields in the wet rice fields and livestock grazed in the fallow swiddens provide manure that is used to increase yields in the paddy fields. Developing a better understanding of these functional linkages among key sub-systems in the composite swiddening agroecosystem is one of the key objectives of this research project. Our study is designed to assess the contribution that flows of nutrients between these subsystems make to maintaining nutrient balances in the system as a whole.

II Description of the Study Site

In order to collect nutrient flow data in a controlled fashion, an experimental site was established in Ban Tat which is a small hamlet in the mountain-valley realm of the Northwestern Mountains. A stream flows through the settlement which is sited in a narrow valley surrounded by steep mountain slopes. The experimental site is located in a small watershed with the area of 3.54 ha at east longitude: 105 degrees 11' 92'' and north latitude: 20 degrees 92' 82.''

The rainy season starts in May with more solid rain in July, August and September, after which the rainfall declines until the end of the rainy season in December. Rainfall recorded from May to December was 1,756 mm in 2000, 2,262 mm in 2001 and 2,045 mm in 2002. The maximum daily rainfall recorded was 210.8 mm on September 11 and 112.6 mm on July 22 in 2001 and 80.2 mm on October 23 in 2002. On 6 days each in 2001 and 2002 there was rainfall of more than 30 mm/hr. Such heavy rainfall is the main cause of soil erosion.

The experimental site has three components: The first part is secondary forest which covers 2.47 ha, the second part is swidden (0.76 ha), and the last is the paddy field in the valley at the base of the hill slope (0.21 ha). The average slope of the hill is from 29–36 degrees.

The pattern of land-use in the watershed is forest (bamboo and trees) on the top slope and beside the swidden, the swidden and fallow swiddens with regenerating forest in the middle slope, and paddy fields in the valley. In the swidden part, the cropping pattern was as follows: in the first year (2000), it was pure upland rice. In the second year (2001), there were three treatments (types) of land use: upland rice, cassava, and fallow. In the third year (2002), there were two types of land use: agroforestry (*Melia* intermixed with cassava) and fallow. In the wet rice field two rice crops were grown per year in the spring and winter seasons. Soils at the site were sandy and extremely acid. Total nitrogen, total phosphate and available potassium, CEC, and organic carbon were all very low. The physical and chemical properties of the soil in the swidden field prior to clearing the forest and in the paddy field are shown in Table 1.

Table 1　Physical and Chemical Properties of the Surface Soil

Unit	Upland Soils	Paddy Soils
Soil texture (%)		
Sand	47.50–58.20	51.20–62.70
Limon	24.50–33.00	18.00–27.90
Clay	12.10–24.40	9.40–30.80
Bulk density (gram/cm^3)	1.04–1.32	1.0–1.59
Particle density (gram/cm^3)	2.5–2.6	2.5–2.6
Acid soils: pH_{kcl}	3.61–4.03	3.73–4.42
Available of P_2O_5 (mg/100 g soils)	0.30–4.00	1.20–5.40
Available or active ion iron (mg/100 g soils)	5–42 (high)	25–100
Available N (mg/100 g soils)	7.0–8.0	4.0–5.0
Available K_2O (mg/100 g soils)	6.40–28.00	7.30–17.70
SiO_2/R_2O_3	< 2.0	< 2.0
C/N ratio	< 13.00	< 11.00
K_2O (%)	4.76–5.36	4.78–4.76
Nitrogen (%)	0.07–0.19	0.06–0.17
MgO and CaO	poor	poor
Organic matter (OC %)	0.26–1.91	0.47–1.88
CEC (less than 10 meq/100 g clay)	5.50–8.80	6.30–7.83 (low)
High in aluminum saturation (%)	22.30–33.70	7.33–13.91

III Conceptual Approach and Research Design

Analysis of soil nutrient balance is a method of assessing agroecosystem sustainability that has been widely used in Southeast Asia [Patanothai 1998]. Nutrient balance is assessed by using an input-output model [Patanothai 1996]. In order to assess the nutrient balance in the composite swiddening system, we need to measure all of the nutrient flows into and out of its swidden and paddy field components. The extent to which the soil nutrients in each subsystem are in balance is established by comparing the quantities of all the nutrient inputs into the system from external sources (e.g., nutrients carried in irrigation water flowing into the paddy field, nutrients contained in rice seed planted in the swidden) with the quantities of nutrients removed from the subsystem as outputs to other subsystems (e.g., soil eroded from the swidden to the paddy field, outflow of water from the paddy field). Only inputs from external sources and outputs from the subsystem to other subsystems are measured. Nutrients that are recycled within the system (e.g., nutrients contained in the plant biomass that are burned to clear the swidden and are retained in the form of ash; rice stubble in the paddy field that is plowed under to prepare the soil for the new crop) do not affect the balance.

Because the composite swidden agroecosystem of Ban Tat is very complex, our limited resources did not permit us to study the functioning of the total system. Instead, we have focused on its two most important subsystems from the standpoint of human subsistence requirements: the swidden subsystem on the hill-slopes and the paddy field subsystem in lower areas. These two sub-systems are functionally linked to each other by the flow of water that transfers nutrients from the swiddens on the hill slopes to wet rice fields in the valley. For each subsystem we formulated models incorporating all important inputs and outputs (Figs. 1 and 2). These models were used to design the plan for data collection at the field site in Ban Tat.

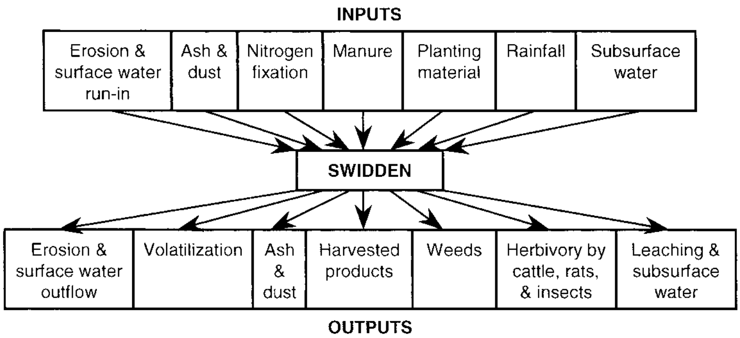

Fig. 1 Input-Output Model for the Swidden Field Subsystem

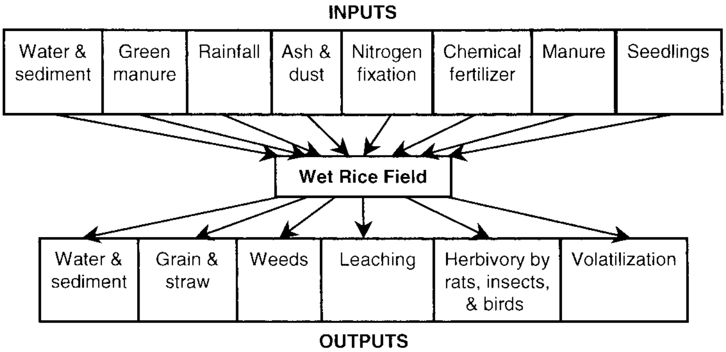

Fig. 2　Input-Output Model for the Wet Rice Field Subsystem

III–1 *The Swidden Field Subsystem*

The input-output model for the swidden subsystem is shown in Fig. 1. Key inputs and outputs in this model include:

a) Soil erosion: soil is eroded by heavy rains or strong winds. Winds blow soil in or out of the field and surface run-off from the rainfall carries soil and dissolved nutrients down the slope. In-flowing surface water from upland areas of forest also brings in soil and dissolved nutrients. In our case study, soil erosion is mostly caused by the rainfall; erosion is very small.

b) Subsurface water: it runs under the surface soil layer and it carries nutrients away with it from the swidden field.

c) Nutrient leaching: nutrients are leached downward through the soil layers and then flow laterally down the slope.

d) Rainfall: rainwater contains nutrients, especially nitrogen formed by lightening.

e) Organic materials: inputs such as seeds and other planting materials.

f) Nutrients carried by dust and ash: carried in by wind from the surrounding burning fields as well as lost through convection during burning.

g) Nutrients in fertilizer, green manure, and night soil: when transplanting or tending to crops, farmers may apply a variety of fertilizers.

h) Output of nutrients by harvesting plants: such as grains, roots, and other plant parts.

i) Weeds: they are an output when farmers pile them outside the edge of the field but are often recycled in the swidden fields.

j) Plant consumption by cattle, rats, and insects: herbivores may remove nutrients when they eat the plants but deposit their wastes outside of the field.

k) Nitrogen fixation by leguminous plants (usually weeds) and microorganisms.

l) Volatilization: the loss of nutrients into the atmosphere in gaseous form. This output is expected to be very small in the swidden field.

III–2 *The Wet Rice Field Subsystem*

The input-output model for the wet rice field subsystem is presented in Fig. 2. Nutrient inputs and outputs for the wet rice field subsystem include the following:

Inputs

a) Water and sediment that comes from the swidden fields through irrigation and flooding
b) Green manure brought into the field by farmers
c) Rainfall
d) Ash and dust brought in by the winds from the surrounding areas
e) Nitrogen fixation by plants in the field
f) Chemical fertilizers
g) Manure brought in by the farmers
h) Transplanted seedlings

Outputs

a) Water and sediment that flow out of the field in drainage and during flooding
b) Grain and straw taken out after harvesting
c) Weeds that are taken out at weeding time
d) Leaching of the soil
e) Herbivory by rats, insects, birds
f) Volatilization

IV Methodology

In order to measure nutrient flows in the research site, we set up 6 run-off plots in the swidden land and 3 run-off plots in the secondary forest for measuring nutrients lost through erosion on the second and the first part respectively. We set-up 8 waters samplers for calculating leaching of nutrients at 3 different depths on the first and second parts, and 6 sets of lysimeters and some weirs in and at the border of the paddy field for calculating changes in nutrients in the paddy field. An automatic rain gauge was set up to record rainfall and collect rainwater for nutrient measurement. Because the quantity of nutrients in the rain water was found to be small (10 kg/ha/yr), measurement was done only in the first year of the experiment.

Data on nutrient flows relating to crop management were collected by interviewing farmers about the quantities of inputs and outputs from their fields and collecting samples of plant materials for chemical analysis. Removal of nutrients by herbivores was estimated by comparison of the biomass of sample plots protected with wire mesh screening with unprotected plots in the field.

V Assessment of Nutrient Balances

Nutrient balances were calculated for the swidden in each of the first two years of cultivation, both for the rice treatment in years 1 and 2, and the cassava treatment in year 2. For the third year of the experiment, a nutrient balance was calculated for the entire hill slope area in the watershed including the fallow swidden, the third year cassava treatment, and the secondary forest on the upper slopes. For the wet rice field, nutrient balances were calculated for the first and second years of the experiment. Finally, the overall nutrient balance of the composite swidden system over a three-year period was calculated.

V–1 *Nutrient Balance of the Rice Swidden Field*

Data collected on the nutrient inputs and outputs of nitrogen, phosphorous and potassium for hill rice in the swidden field in 2000 and 2001 are presented in Table 2.

As Table 2 shows, the nutrients contained in seedlings and rainfall are the only major inputs into the subsystem. The farmers never apply fertilizer to the rice in the swidden field. Thus, nutrient inputs are very small, with N (around 11 kg) the most significant. The outputs are much larger with burning and erosion and leaching the major factors. Consequently, nutrient balance values for N, P, K in both years are all highly negative. The N deficit in 2000 was over 174 kg, primarily due to losses when the swidden was burned, and almost 123 kg in 2001, mostly because of erosion and leaching. The P balance was less unfavorable, with a deficit of 21 kg in 2000, with most loss caused by burning, and 16 kg in 2001, largely as a result of erosion and leaching. The deficit of K was 390 kg in 2000 and 725 kg in 2001, with erosion and leaching the main cause in both years.

V–2 *Nutrient Balance of the Cassava Swidden Field*

Data on inputs and outputs of nutrients to the part of the swidden plot with the cassava treatment in the second year of cultivation is presented in Table 3.

Table 2 Nutrient Balance for Rice Swidden (kg/ha)

Input	2000			2001		
	N	P	K	N	P	K
Seedlings	0.46	0.10	0.10	1.00	0.10	0.30
Rainfall	10.00	0.00	0.00	10.00	0.00	0.00
Total	10.46	0.10	0.10	11.00	0.10	0.30
Output						
Erosion, surface outflow, and leaching	31.91	3.75	298.37	88.40	9.18	718.01
Burning	130.08	13.38	76.90	24.87	6.24	2.46
Harvesting	9.87	4.13	11.68	7.00	0.90	1.90
Herbivory	2.60	0.22	2.66	2.60	0.22	2.66
Total	174.46	21.48	389.61	122.87	16.54	725.03
Overall balance	–164.00	–21.38	–389.51	–111.87	–16.44	–724.73

In comparison to the second year rice swidden, the cassava treatment, although having negative balances for all nutrients, suffered somewhat lower losses of N and K than did rice in the same year. One factor, although only a minor one, is that cassava was not eaten by herbivores. The most important causes of nutrient loss from the cassava were erosion, run-off and leaching. Removal of nutrients in the harvested tubers was a relatively minor output.

V–3 *Nutrient Balance of the Hill Slope Component*

In the third year (2002), input and output data were collected for the entire hill slope in the experimental watershed. Erosion and run-off water from the entire hill slope flow into the paddy field. Cassava was planted on 14 percent of the total area, natural fallow covered 8 percent, and secondary forest covered 74 percent. Inputs and outputs for all three land use types have been combined into a single balance of nutrients for the hill slope component of the watershed (Table 4).

Nutrient inputs and outputs for the hill slope were very low although there were negative balances for all nutrients. However, losses were from 5 to 10 times less than from the cultivated swidden in the first and second years. Most nutrient losses were the result of erosion, run-off and leaching from the relatively small area in the watershed under cultivation or in the early stages of fallow. Clearly, secondary forest is a superior land use in terms of preventing erosion losses of nutrients from sloping lands.

Table 3 Nutrient Balance for Cassava Treatment of the Swidden Field in the Second Year (2001)

(kg/ha)

Input	N	P	K
Planting material	4.10	0.50	6.10
Rainfall	10.00	0.00	0.00
Total	14.10	0.50	6.10
Output			
Erosion, surface water outflow, and leaching	72.69	9.19	613.09
Burning	24.87	6.24	2.46
Harvesting	17.30	2.20	25.50
Total	114.86	17.63	641.05
Overall balance	–100.76	–17.13	–634.95

Table 4 Nutrient Balance for the Hill Slope Land Component in the Third Year (2002)

(kg/ha)

Input	N	P	K
Crop management	0.006	0.002	0.002
Rainfall	10.000	0	0
Total	10.006	0.002	0.002
Output			
Harvesting	2.105	0.464	2.167
Erosion, run-off, leaching	27.889	1.854	81.560
Total	29.994	2.318	83.727
Overall balance	–20.204	–2.316	–87.725

V–4 *Nutrient Balance of the Wet Rice Field*

Table 5 presents input and output data for the experimental wet rice field for 2000 and 2001.

Nutrient inputs and outputs for the wet rice field were relatively close to being in balance. Nitrogen was in deficit by 13 kg/ha in 2000 but had a small positive balance (11 kg) in 2001. Values for phosphorous were positive for both years while potassium was in deficit in both 2002 and 2001. Nutrients brought into the subsystem by water flowing off of the hill slope make a major contribution to achieving balance for N and K.

V–5 *Overall Nutrient Balance for the Composite Swidden System*

By combining data on nutrient inputs and outputs for three years for the swidden and secondary forest on the hill slope and the wet rice field in the valley of our experimental watershed we were able to calculate the overall nutrient balance for the composite swiddening system (Table 6). Nutrient inputs occur through crop management (introduction of planting materials and application of fertilizer) and rainfall. Outputs occur through harvesting, loss to herbivores, and run-off of water out of the wet rice field. It should be remembered that in the case of our site, nutrient outputs from the hill slope in the form of erosion and leaching constitute inputs to the wet rice field so they are not included in the calculation as a loss or gain for the total system.

For the three-year period, the system shows an overall positive balance of phosphorous (220 kg/ha) but quite large deficiencies of nitrogen (159 kg/ha) and, especially, potassium (867 kg/ha). Most of the gains of P in the system come from excessive application of chemical fertilizer in the paddy field (Table 5). Losses of N and K occur mainly in the harvest and as the result of water flowing out of the wet rice field. Some of these nutrient losses become inputs into lower-lying paddy fields and some are lost into the river, especially at times when the wet rice fields overflow due to flooding caused by heavy rains. The deficiency of N could be made good through a relatively small increase in the rate of application of chemical fertilizer. It may be more difficult to compensate for loss of potassium. Farmers in Ban Tat do not currently apply chemical fertilizer containing K.

Table 5 Nutrient Balance of the Wet Rice Field (kg/ha)

Input	2000			2001		
	N	P	K	N	P	K
Seedlings	1.95	0.63	1.87	1.10	0.20	0.30
Rainfall	10.00	0.00	0.00	10.00	0.00	0.00
Organic fertilizer	9.90	7.42	71.78	0.00	0.00	0.00
Chemical fertilizer	38.30	65.56	0.00	115.00	98.00	0.00
Water inflow	97.33	9.68	337.98	227.23	25.23	379.90
Total	157.48	83.29	411.63	353.33	123.43	380.20
Output						
Harvesting	95.65	30.56	109.73	70.40	17.70	41.00
Herbivores	4.70	2.10	6.89	4.70	2.10	6.89
Water outflow	70.19	8.81	337.35	267.27	22.34	391.52
Total	170.54	41.47	453.97	342.37	42.14	439.41
Overall balance	–13.06	41.82	–42.34	10.96	81.29	–59.21

Table 6 Overall Nutrient Balance of the Composite Swidden System for 3 Years (kg/ha)

Input	N	P	K
Crop management (hill slope)	1.57	1.22	2.22
Crop management (wet rice field)	291.40	322.00	124.80
Rainfall	30.00	0	0
Total	322.97	323.22	127.02
Output			
Harvesting (hill slope)	27.84	3.72	39.74
Harvesting (wet rice field)	267.80	78.20	335.20
Outflow of wet rice field	186.73	21.39	618.60
Total	482.37	103.31	993.54
Overall balance	–159.40	+ 219.91	–866.52

VI Conclusion and Discussion

Nutrient balance analysis reveals that the composite swidden system as it is currently managed by the farmers in Ban Tat is not fully in balance. Nutrient losses from the swidden subsystem are much higher than inputs, largely as a result of burning and erosion and because the farmers do not apply any fertilizer to swidden fields. This might be taken to suggest that swiddening is unsustainable but, because swidden agriculture involves a multi-year cycle of cultivation and fallow, it will be necessary to collect nutrient input and output data for an entire cycle before it will be possible to calculate a final nutrient balance for this subsystem.

For the paddy field, K was in deficit but N and P were essentially in balance. This balance was achieved only because a large share of the nutrients lost from the swidden become inputs into the wet rice field. Nutrients from water flowing off the hill slope into the paddy field supplied more than 60 percent of the nitrogen inputs and more than 80 percent of potassium inputs to this subsystem in the first year of the experiment, and 64 percent and 100 percent in the second year. This finding suggests that assessment of the sustainability of the wet rice subsystem in composite swiddening must take account of interactions between the swiddens and the paddy fields within the watershed.

At the level of the composite swidden system as a whole, nutrient inputs and outputs are not in balance. Over the three-year period for which data have been analyzed, outputs of N exceeded inputs by 159 kg/ha and outputs of K exceeded inputs by 867 kg/ha. Only P shows a positive balance with inputs exceeding outputs by 103 kg/ha. Thus, under current management practices, the composite swidden system may not be sustainable in the long-term at least if current management practices remain unchanged.

Comparison of the nutrient balances for the swidden and the wet rice field reveals that the negative imbalance of nutrient inputs to outputs is much greater in the swidden field than in the paddy field. Thus, if the farmers at Ban Tat did not practice composite swiddening but instead relied exclusively on swiddens to meet their food requirements, their agriculture would be much less sustainable than it is now. This confirms the main hypothesis that it is the fact that most households simultaneously cultivate both wet rice fields and swiddens that explains the relatively high evident sustainability of the land use system in Ban Tat.

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Impact of Agricultural Practices on Slope Land Soil Properties of the Mountainous Region of Northern Vietnam: A Case Study in Bac Ha District, Lao Cai Province

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Abstract

In the mountainous region of Northern Vietnam, there are various systems for agricultural land use. This paper describes the impact of agricultural practices on the original properties of slope land soils with special reference to changes in soil fertility and weathering in relation to soil erosion. Soil fertility was not extremely low in the higher commune, where the cooler climate would be more dominant factor controlling productivity. Therefore, the people made well-managed terraces to maintain their fields. On the other hand, in the lower commune, shifting cultivation is a dominant way of agriculture supported by the warmer climatic condition. Weathering status of soils was not greatly different among the three communes, but the current climatic conditions would affect the reactivity of soils. The clay dispersion ratio of all the sites studied was very low. In addition, the clay dispersion ratio and clay content were not different among different land uses. This means that soil erosion would not have a strong impact under current farming systems in the three communes. However, activity ratios of Al and Fe (Alo/Ald and Feo/Fed) became lower after cultivation, and therefore, in the long term, slight but continuous erosion might have occurred to reduce the activity of soils.

Keywords: soil fertility, soil weathering, terracing, contour planting, shifting cultivation, soil erosion, slope land, Bac Ha, Vietnam

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I Introduction

In the mountainous region of Northern Vietnam, most of the people live by practicing agriculture on slope land, in addition to cultivating lowland paddy in small valleys. The local farmers utilize the mountain area thoroughly. Due to an increase in population density and/or economic necessity, unused arable lands have already become scarce in many parts of the mountainous area of Southeast Asia. They have to depend on the current land resources.

To evaluate the productivity of a farm field, soil scientists mostly depend on analytical data on soil quality and fertility, including the pH value, clay content, the amounts of exchangeable cations, available phosphorus, nitrate and ammonium, total carbon, and total nitrogen, and so on. This is an appropriate approach when we would like to know the current condition of the soils in the farm yard. Based on the analytical data, we can prescribe a recipe for fertilizer application for a single crop or several subsequent crops. On the other hand, these analytical data are not considered sufficient to predict the sustainability of the land resources in the long run because they are influenced easily by the agricultural practices or even by the climatic condition. Prediction of sustainability of the land, therefore, should be based on the weathering status of soils because the intrinsic soil properties that do not change easily within a short time can be considered as determining potential productivity. The weathering status of soils can be judged from more qualitative aspects such as clay mineralogy, charge property, and the accumulation of sesquioxides (Fe and Al) [Sakurai 1990].

In addition, in slope land agriculture, soil erosion is usually considered as having serious impacts on the current productivity and sustainability of the land. To evaluate the soil erosion rate, the eroded sediments are usually collected and weighed. However, to install experimental plots for soil erosion to obtain reliable and quantitative data requires large investment and a large area of land. Consequently, for the prediction of soil erosion *in situ*, the Universal Soil Loss Equation (USLE) is often used [e.g., Mitchell and Bubenzer 1980]. The rate for soil loss in a unit area (A) can be predicted by the rainfall (R), erodibility (K), length of slope (L), degree of slope (S), cropping pattern (C), and soil conservation (P). However, all of these aspects should be taken into consideration at the same time to predict the actual amounts of soil loss. In remote areas, it is very difficult to evaluate all of these factors due to the lack of equipment and staff. In addition, since the local topography is quite complex in the mountains, a quantitative evaluation of these factors is almost impossible. Therefore, it is necessary for us to depend on a more simple technique to predict the rate of soil erosion. The clay dispersion rate can be utilized as a direct index of the erodibility of the soils [Itami and Kyuma 1995]. Because most of the severe soil erosion may be caused by the rainfall, the dispersion of clay by rainwater will be one of the most important issues for its prediction. This aspect is partly included in the factor K in the USLE equation. Since we can not control the length of slope (L) and degree of slope (S) easily and can manage the cropping pattern (C) and soil conservation (P) to only a limited extent due to climate and economic rationale of local farmers, the evaluation of erodibility is the most practical and useful information to examine the soil erosion in this area. Dispersion rate of clay particles (<2 μm) can be evaluated by the ratio of dispersible clay in water to that in dispersing media (e.g., NaOH to adjust the suspension pH to 10.0). Especially, after strong weathering, soils are often aggregated by cementing materials such as Fe or Al hydroxides or oxides. Aggregated soils are resistant against water dispersion and therefore resist water erosion.

Soil weathering status is a so-called long term dynamic of soils, while soil fertility and clay dispersion rate are short-term and middle-term dynamics. Therefore, we try to evaluate the sustainability of agricultural land on the slope in our study site with a combined viewpoint of short- to long-term dynamics of soils. Thus, we analyze the agricultural system of slope land in Northern Vietnam in terms of soil weathering status, clay dispersion ratio as well as soil fertility along the toposequence, and evaluate the agricultural practices on slope land soil properties.

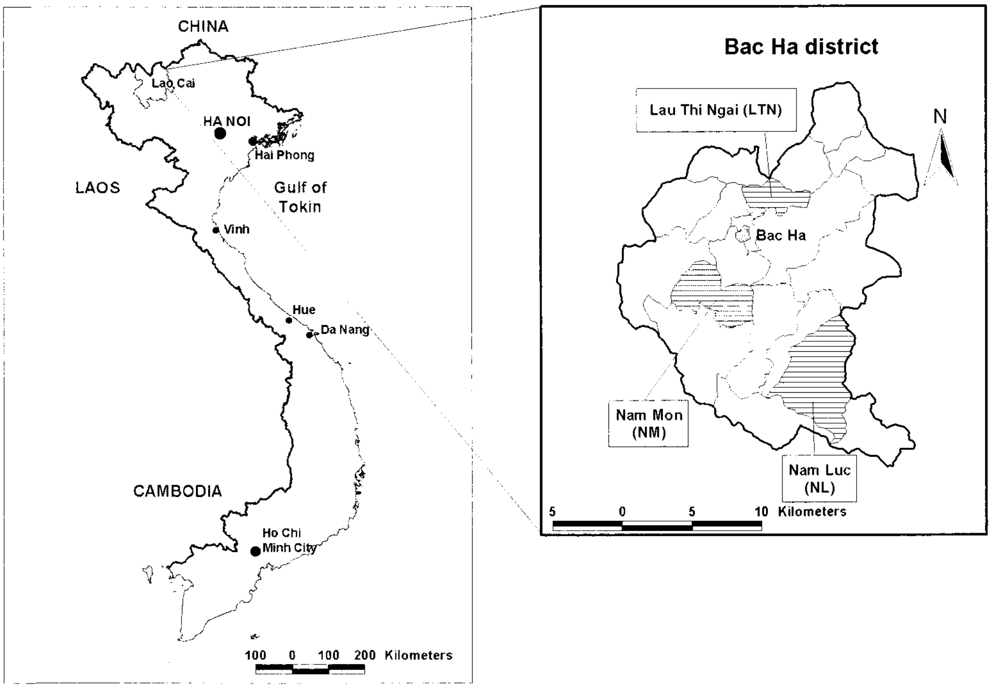

Fig. 1 Location of the Study Sites

II Materials and Methods

II–1 *Study Area*

We selected Bac Ha district, Lao Cai province, as the study area because we found most intensive slope land agriculture here in the mountainous region of Northern Vietnam (Fig. 1). Bac Ha is an upland district with elevation ranging between 100 to 1,500 m a.s.l. It is adjacent to Si Ma Cai district to the north and approximately 20 km south of the border with China. Bac Ha district has 20 communes and one town subdivided into 213 villages. The total population of the district is 45,982, of which 22,667 are women, and 39,285 are ethnic minority people. The population density is 64 persons per square km. There are 17 ethnic groups, with H'mong accounting for 40 percent of the population. The natural area of Bac Ha district is 68,678 ha, of which 12,442 ha is agricultural land (accounting for 18.1 percent), forest land is 19,101 ha (27.8 percent), and unused land is about 36,232 ha (52.7 percent). The average elevation is 1,000 m (the highest peak is 1,532 m). According to Koppen's classification, this climate is tropical monsoon with dry and cool winter. The average rainfall is 1,800 mm per year and the average temperature is 18.3°C (semi-temperate or subtropical climate). The main agricultural crops are upland rice, paddy rice, and maize. Several other crops such as cassava, tea, and soybean are also cultivated in a small scale [HEDO 2001].

Three communes, Lau Thi Ngai, Nam Mon, and Nam Luc located at approximately 104° 25' E and 22° 30' N were selected for study in Bac Ha district. Three communes are located within 12 km (west to east) and 18 km (north to south) distance with each other in the steep mountainous region. Selected information on three communes is shown in Table 1. Lau Thi Ngai village is located on the top of the hill and has the highest elevation and coolest climate (hilltop commune). Nam Mon is located on the middle of the slope and has intermediate elevation (mid-slope commune). Nam Luc is located along the river at the lowest part of the mountainous region with a warmer local climate than the other two (foothill commune).

Parent materials in the hilltop commune and mid-slope commune are phyllite, which results in soil with a fine clayey nature. In the foothill commune, the parent material is granite, which results in soil with a very sandy, acidic nature resulting in poor soil fertility. Soil types by the Vietnamese soil classification map (1978) are allocated as Organic yellow-red soils on weathered rocks (hilltop commune), Red-yellow soils on weathered rocks (mid-slope commune), and Yellow-red soils (foothill commune). Due to shallow soil layers (30–50 cm) with a weak development of the B horizon in hilltop and mid-slope communes, the soils could be classified as Typic Dystropepts with some Typic Hapludults by the U.S. Soil Taxonomy [Soil Survey Staff 1992]. On the other hand, in the foothill commune, though outcrops of granite are found on sloping land everywhere, soil depth is often deeper than 1 m. Clay accumulation and the development of the B horizon is weak. Therefore, Typic Dystropepts and Typic Hapludults could be appropriate.

Table 1 Information on the Communes Studied

Commune	Lau Thi Ngai (LTN) (Hilltop Commune)	Nam Mon (NM) (Mid-slope Commune)	Nam Luc (NL) (Foothill Commune)
Elevation (m)	1,090–1,640	300–1,950	100–800
(Sampling site)	1,250	650	300
Parent rock	Phyllite	Phyllite	Granite
Soil type	Organic yellow red	Red yellow	Yellow red
Erosion	Moderate	Moderate	Severe
Organic matter	Few	Few	Very few
Weathering	Moderate	Moderate	Strong
Number of village	7	12	11
Household	227	398	477
Population	1,246	2,125	2,600
Ethnic composition (%)	H'mong: 88 Dao: 5 Kinh: 7	H'mong: 52 Nung: 28 Dao: 9 Kinh: 0.4 Other: 10	Dao: 52 H'mong: 26 Tay: 17 Kinh: 5
Agricultural land (ha)	576	471	1,218
Maize (ha)	120	201	396 (incl. cassava)
Lowland paddy (ha)	70	85	31
Upland rice (ha)	40	100	791
Fallow (ha)	349	85	—
Forest (ha)	473	410	910
Farm size (lowland/family)	0.31	0.21	0.06
(upland/family)	0.70	0.76	2.49
Yield (t/ha)			
Maize	1.2	1.2–1.7	1.4
Paddy (distribution)	Terrace 2.5–3.0 (new variety) 1.5–1.7 (traditional)	Terrace and hollow 2.7–3.0 (terrace) 4.7–5.0 (hollow)	Hollow 5.5 (hollow)
Upland rice	0.8	0.7	1.0
Variety (maize)	Traditional	Traditional 85 % New variety 15 %	Hybrid (mostly)
Cropping pattern			
Maize	Single	Single 80 % Double 20 %	Single or Double
Paddy	Single	Single 80 % Double 20 %	Single or Double
Upland rice	Single	Single	Single
Chemical fertilizer			
Maize	No	N and P	N and P
Paddy	NPK+manure	N and P	N and P + NPK, green manure
Upland rice	No	P	No
Paddy field reclamation	long time ago	Long time ago	Since 1995
Main food	Maize	Maize and upland rice	Upland rice

II–2 *Soil Samples and Analytical Methods*

Soil survey points in each commune were selected from every representative land use and from natural forests. The number of the investigated pedons was 6 in the hilltop commune (2 forest, 2 maize, 1 upland paddy, and 1 lowland paddy), 6 in the mid-slope commune (1 forest, 1 forest fallow, 1 maize, 2 upland paddy, and 1 lowland paddy), and 5 in the foothill commune (1 forest, 1 fallow, 1 cassava, 1 upland paddy, 1 lowland paddy). Soil samples were collected from surface and subsurface horizons. Mostly surface soils (A or Ap horizon) were collected at the depth of 0 to 20 cm from the upland field, 0 to 10 cm from the paddy field in the terrace, and 0 to 5 cm from the forest. Subsurface soils were collected beneath this depth at approximately 20 cm interval. Soil samples were air-dried and crushed to pass through a sieve with a 2 mm mesh.

The pH in water and 1 M KCl solution was measured by the glass electrode methods, at the soil: solution ratio of 1 : 2.5 and designated as pHw and pHK hereafter. Exchangeable H was extracted with 1 M KCl for 1 h and determined with the titration method (designated as ExH). Exchangeable cations were extracted twice with 1 M ammonium acetate at pH 7.0, and the concentration of Ca, Mg, and K (designated as ExCa, ExMg, and ExK) was measured by atomic absorption spectrophotometer (Shimadzu, AA-610S). The ammonium ion absorbed in the residue was replaced by 10 percent NaCl and determined with distillation and titration methods as cation exchange capacity (CEC). Available phosphorus was determined by the Olsen method (designated as AvP). Organic matter (OM) content was determined by the Walkley-Black method. Soil samples were digested by HNO_3-H_2SO_4 and the contents of N, P, K were determined by distillation- titration method for N, spectrophotometry for P, AAS for K, respectively (designated as TN, TP, TK). Soil texture was determined by the pipet method. Water dispersible clay and silt contents were measured by the pipet method after 4 h reciprocal shaking at the soil to water ratio of 10 g to 1 L. Al and Fe oxides and hydroxides were extracted twice with an acid ammonium oxalate solution (0.2 M, pH 3.0) by reciprocal shaking in the dark for 1 h, at a soil to solution ratio of 1 to 25 [Mckeague and Day 1966]. They were extracted twice with a citrate-bicarbonate mixed solution buffered at pH 7.3 with the addition of sodium dithionite for 15 min. at 75 to 80˚C, using a soil to solution ratio of 1 to 100 [Mehra and Jackson 1960]. Al and Fe contents in the extract were designated as Alo and Feo for the former extractant, and Ald and Fed for the latter. The contents of Al and Fe were determined using a sequential plasma spectrometer (Shimadzu, ICPS-1000IV). Clay minerals were identified by X-ray diffraction method (Shimadzu, XD-D1w). The point of zero charge equivalent as point of zero salt effect (PZSE) and σp (residual charge at the pH of PZSE) was determined by the modified salt titration method (STPT method) [Sakurai *et al*. 1988].

III Results and Discussion

III–1 *Agriculture Conditions in the Communes Investigated*

Comparison among the three communes is summarized in Table 1, although some information still remains unknown. Each commune is composed of different ethnic groups. The H'mong generally occupy the higher land, the Dao occupy the lower land, and several other groups are mixed with them. Compared with the agricultural land, forest area is 20 percent smaller than the agricultural land in each commune. Among agricultural land, maize cultivation area is the largest in hilltop and mid-slope communes, followed by lowland paddy area in the hilltop commune and upland rice area in the mid-slope commune. On the other hand, upland rice field is the largest, followed by maize and smaller area of paddy in the foothill commune.

Agricultural land area is the largest in the foothill commune, where they mostly depend on shifting cultivation. Lowland paddy cultivation was initiated in 1995. They have not felt the strong necessity for intensive management of their agricultural land, such as terracing to prevent against soil erosion, having a more favorable climate than the other communes. Even though the average farm size is the largest among the three communes, 2.49 ha of upland field and 0.06 ha of lowland field per family, shifting cultivation with long-term fallow is impossible due to limited land availability. In addition to rice for home consumption, they also produce maize and cassava for sale because of the easy access to the main road. They used a hybrid variety of maize to get higher yield. Double cropping of upland rice and maize is not common, probably due to the poor soil conditions and less water availability in the dry season.

The hilltop commune makes beautiful terraces to produce every crop. Along the valley, they have constructed lowland paddy fields, while they produce both maize and upland rice on the slopes. The width of the terrace is very narrow, generally 2 to 5 m along the slope, while along the valley it is much wider, depending on the topography. Terraces have been introduced since before their grand father's generation, probably based on technology transfer from China. The average farm size is 1 ha, of which 70 percent is upland and 30 percent is lowland. Small farm size was thought to accelerate terrace making in order to shift their farming from slash and burn agricultural system to continuous cultivation. Since the hilltop commune is located at an elevation of 1,250 m, crop yields are lower than in the foothill commune due to cooler climate. The cropping pattern is single cropping. Since the use of chemical fertilizer is still limited, the yield of maize and lowland paddy is not high.

The mid-slope has an intermediate nature of farm size, cropping pattern, and main food. The width of terrace is also wider than that in the hilltop commune. The wider variation of ethnic groups and their different food habits may affect these farming practices. Their typical land use is contour planting, and therefore, the intensity of land management can be considered intermediate.

Assuming that one person (adult) needs 2,500 kcal per day and all the consumption calories are obtained from rice, rice will be necessary in an amount of 0.325 t per person per year [Watanabe *et al*. 2003]. To support the population in the foothill commune, where 2,600 persons live (Table 1), approximately 845 t of rice is necessary. The total harvested amount of upland rice can be calculated as 791 t (791 ha×1.0 t/ha). This amount is, therefore, slightly lower than the demand. Supplementary rice will come from the lowland paddy where the total amount of rice, (31 ha×5.5 t/ha = 170.5 t), is produced. Total amount is slightly higher than demand and they may eat some maize also. This calculation leads us to conclude that if the population continues to increase, they will not be able to support themselves in the future. To increase the yield of crops by intensive cropping management is indispensable for their subsistence. Otherwise, they have to open new land in the forest, which will easily lead to a degradation of their local ecosystem within a short term. Thus, it can be predicted that they will soon start more intensive management of their land, and terracing must be one promising method for soil protection. Other type of cash crops using tree species such as fruits or cardamom may be another way to get more cash income to buy rice or maize for the subsistence.

III–2 *Soil Properties*

Chemical, physical, and mineralogical properties of the soils are shown in Tables 2 to 4, where averaged values for soils from forests and crop fields are also included. Original soil properties before utilized for agricultural purpose are best represented in the forest soils. When the parent materials of soils were rather similar, the magnitude of cation exchange capacity (CEC) could be one of the indicators of weathering. Upon weathering, CEC value becomes smaller due to loss of the active exchange site for cation retention. The CEC value reflects the sum of negative charges on soil particles arising from both organic matter and clay minerals together with oxides and hydroxides of Si, Fe, and Al. On the other hand, the amount of Fed becomes higher as a result of relative accumulation of Fe compared with other elements during weathering. Al and Fe oxides and hydroxides would be more crystallized upon weathering due to loss of active hydroxyl groups, then Alo/Ald and Feo/Fed ratios become smaller, and eventually fell to a value less than 0.10. At the ultimate weathering condition, these values would become less than 0.01. In addition, point of zero salt effect (PZSE) value becomes higher reflecting on the relative accumulation of oxides and hydroxides of Fe and Al. Other soil properties, such as the amount of exchangeable cations, available phosphorus, and organic matter, fluctuate easily with agricultural activities. Clay content will increase with weathering in the soils if there is no occurrence of soil erosion. However, on sloping land, soil erosion occurs continuously in the long term. Thus, it is rather difficult to utilize this value to discuss the weathering status of soils.

Based on these indicators, the weathering status of soils in the three communes can be interpreted as follows. Soils in the hilltop commune show the highest value of CEC with a highest amount of organic matter. Fed values were also highest. On the other hand, soils in

Table 2 Chemical, Physical, and Mineralogical Properties of Soils in Lau Thi Ngai Commune

Items*		pHw	pHK	CEC	ExH	ExK	ExCa	ExMg	ExSum	OM	TN	TK	TP	AvP	Clay	Silt	Sand	WDC	WDS	Alo	Fed	AloAld	FeoFed	PZSE	σp
Soil Name**				———— cmol (+) kg^{-1} ————						———— g kg^{-1} ————					————————— % —————————									cmol (+) kg^{-1}	
LTN-Fr1	A	4.4	4.1	24.59	1.30	0.42	7.20	1.80	9.42	6.93	0.350	1.45	0.25	11.2	19.5	19.3	61.2	2.2	5.6	n.d.	n.d.	n.d.	n.d.	4.32	2.14
	B1	4.6	4.4	11.09	2.85	0.17	1.62	0.18	1.97	1.80	0.130	1.37	0.20	2.2	24.8	26.9	48.3	0.3	17.0	n.d.	n.d.	n.d.	n.d.	4.19	0.83
	B2	4.6	4.4	10.46	3.10	0.14	1.44	0.36	1.94	1.42	0.102	1.45	0.22	3.2	22.6	24.4	53.0	2.2	8.3	n.d.	n.d.	n.d.	n.d.	4.39	0.53
LTN-Fr2	A1	4.2	3.9	20.27	7.41	0.32	1.44	0.36	2.12	5.29	0.261	0.84	0.22	9.5	30.9	16.0	53.2	1.2	26.3	0.4	3.13	0.52	0.23	4.14	1.33
	B	4.1	3.9	14.77	7.28	0.11	0.90	0.18	1.19	2.84	0.127	0.78	0.17	2.0	17.6	33.6	48.9	3.6	8.2	0.2	3.33	0.28	0.09	4.35	0.45
	Ave.	4.4	4.1	16.24	4.39	0.23	2.52	0.58	3.33	3.66	0.194	1.18	0.21	5.6	23.1	24.0	52.9	1.9	13.1	0.3	3.23	0.40	0.16	4.28	1.06
LTN-M1	Ap	5.0	4.7	11.82	0.16	0.32	3.60	1.80	5.72	2.05	0.105	1.54	0.29	7.9	24.6	22.7	52.7	2.1	27.9	0.1	3.05	0.30	0.12	4.58	1.90
	B1	5.4	5.3	6.82	0.09	0.14	2.70	0.90	3.74	0.70	0.075	1.72	0.12	3.9	21.3	28.5	50.3	1.9	10.6	0.1	3.57	0.10	0.03	5.52	0.45
	B21	5.5	5.3	8.31	0.09	0.13	2.88	1.62	4.63	0.50	0.063	1.54	0.20	2.9	20.5	32.6	47.0	0.9	6.4	0.0	3.63	0.07	0.02	5.42	0.50
	B22	5.7	5.5	22.15	0.09	0.11	2.16	1.80	4.07	0.70	0.065	1.84	0.22	2.8	15.8	34.1	50.1	3.6	4.2	0.1	3.74	0.12	0.04	6.13	0.10
LTN-Fa	A/B1	4.7	4.4	7.41	0.90	0.12	2.16	0.54	2.82	1.47	0.110	1.65	0.15	4.4	24.3	22.9	52.8	3.9	29.8	n.d.	n.d.	n.d.	n.d.	4.47	0.71
	B2	4.6	4.4	11.09	2.85	0.17	1.62	0.18	1.97	1.80	0.130	1.37	0.20	2.2	26.9	24.9	48.3	1.9	11.9	n.d.	n.d.	n.d.	n.d.	4.70	0.38
	B3	4.7	4.4	6.14	0.84	0.11	1.26	0.18	1.55	0.83	0.081	1.73	0.12	3.9	29.8	20.4	49.8	0.3	13.1	n.d.	n.d.	n.d.	n.d.	4.81	0.00
LTN-M2	0–20	4.2	4.0	19.74	5.95	0.40	1.80	0.90	3.10	4.80	0.225	0.77	0.20	5.1	38.0	15.1	46.9	0.5	31.5	n.d.	n.d.	n.d.	n.d.	3.88	2.00
	20–40	4.1	3.9	14.30	5.92	0.39	1.44	0.36	2.19	3.13	0.139	0.87	0.17	2.5	40.5	17.6	41.9	0.3	29.2	n.d.	n.d.	n.d.	n.d.	4.20	0.28
LTN-Up	Ap1	4.0	3.8	20.52	7.38	0.25	1.80	0.36	2.41	5.68	0.267	0.98	0.26	6.1	42.4	15.0	42.6	2.7	41.3	0.3	2.96	0.36	0.17	4.08	2.00
	Ap2	4.1	3.9	20.07	7.62	0.16	1.44	0.36	1.96	4.60	0.225	0.94	0.20	9.6	42.5	13.3	44.2	1.6	32.5	0.3	2.53	0.41	0.20	4.11	1.58
	B1	4.1	3.9	16.09	7.19	0.10	0.72	0.18	1.00	2.30	0.120	0.84	0.21	5.4	49.4	12.7	37.9	1.8	45.6	0.3	3.83	0.34	0.13	4.22	0.53
	B2	4.2	4.0	15.67	6.29	0.10	0.72	0.36	1.18	2.45	0.160	0.97	0.17	2.8	48.8	12.8	38.3	1.4	31.8	0.3	3.26	0.30	0.10	4.32	0.46
	B3	4.3	4.0	13.24	5.85	0.08	0.90	0.18	1.16	1.66	0.090	0.82	0.21	4.5	48.0	12.6	39.4	0.8	31.2	0.2	3.76	0.19	0.06	4.37	0.45
LTN-P	Ap1	4.6	4.5	15.82	0.12	0.13	7.74	0.36	8.23	3.08	0.145	1.07	0.20	2.8	43.0	15.4	41.6	2.5	49.2	0.1	3.22	0.16	0.10	4.69	3.85
	Ap2	5.0	5.0	16.08	0.09	0.09	9.00	0.90	9.99	2.35	0.121	1.15	0.17	2.2	41.8	17.2	41.0	1.8	37.9	0.1	3.29	0.14	0.07	4.12	5.69
	B	4.7	4.6	14.91	1.05	0.11	5.04	2.16	7.31	1.57	0.105	1.09	0.12	2.0	47.9	11.6	40.5	2.0	51.9	0.1	3.49	0.17	0.06	4.17	5.08
	Ave.	4.6	4.4	14.13	3.09	0.17	2.76	0.77	3.71	2.33	0.131	1.23	0.19	4.2	35.6	19.4	45.0	1.8	28.6	0.2	3.36	0.22	0.09	4.58	1.53

* pHw and pHK: pH measured in water and KCl solution; CEC: cation exchange capacity; ExH, K, Ca, Mg: Exchangeable H, K, Ca, Mg; Ex Sum: sum of exchangeable K, Ca, and Mg; OM: organic matter; TN, TK, TP: total nitrogen, pottasium, phosphorus; AvP: available phosphorus; WDC: water dispersible clay; WDS: water dispersible silt; Alo: Al extracted by acid oxalate; Fed: Fe extracted by DCB treatment; AloAld, FeoFed: ratio of Alo/Ald andFeo/Fed; PZSE: point of zero salt effect; σp: residual charge at PZSE

** Fr forest; Fa: fallow; M: maize; C: cassava; P: paddy; Up: upland paddy

Table 3 Chemical, Physical, and Mineralogical Properties of Soils in Nam Mon Commune

Items* Soil Name**		pHw	pHK	CEC	ExH	ExK	ExCa	ExMg	ExSum	OM	TN	TK	TP	AvP	Clay	Silt	Sand	WDC	WDS	Alo	Fed	AloAld	FeoFed	PZSE	σp
				cmol (+) kg$^{-1$}						g kg^{-1}					%									cmol (+) kg^{-1}	
NM-Fr	A	4.3	4.1	12.18	1.41	0.25	0.72	1.08	2.05	3.18	0.150	1.41	0.22	1.9	34.2	13.2	52.6	3.1	27.7	0.2	2.44	0.40	0.18	4.10	1.06
	B	4.3	4.1	9.45	1.24	0.16	0.90	0.18	1.24	2.10	0.110	1.24	0.10	3.9	37.8	13.0	49.2	1.2	10.9	0.2	3.01	0.33	0.15	4.21	0.50
	Ave.	4.3	4.1	10.82	1.33	0.21	0.81	0.63	1.65	2.64	0.130	1.33	0.16	2.9	36.0	13.1	50.9	2.2	19.3	0.2	2.73	0.37	0.17	4.16	0.78
NM-M	Ap	5.1	5.0	10.18	0.18	0.19	4.50	0.90	5.59	2.45	0.140	1.56	0.20	3.1	30.4	14.6	55.1	2.4	62.4	0.2	3.20	0.30	0.10	3.95	3.74
	B1	4.8	4.6	7.86	0.81	0.24	1.80	0.90	2.94	0.93	0.080	1.74	0.12	3.1	24.7	15.2	60.1	1.5	22.2	0.1	3.37	0.13	0.05	4.60	0.47
	B2	4.8	4.6	5.53	0.62	0.06	0.90	0.90	1.86	0.73	0.060	1.93	0.15	2.8	23.9	16.0	60.2	1.5	14.9	0.0	3.50	0.12	0.03	4.76	0.41
NM-Fa	A	4.2	4.0	13.15	7.78	0.14	0.72	0.18	1.04	3.82	0.180	1.22	0.17	6.4	43.5	12.3	44.2	1.7	48.5	n.d.	n.d.	n.d.	n.d.	4.12	0.44
	B	4.3	4.0	11.50	1.23	0.17	0.54	0.18	0.89	2.45	0.120	1.23	0.12	3.1	45.4	9.9	44.6	1.1	31.2	n.d.	n.d.	n.d.	n.d.	3.73	1.65
NM-Up1	Ap1	4.2	4.0	13.40	1.33	0.29	0.90	0.10	1.29	4.16	0.210	1.33	0.17	7.2	47.0	12.1	40.9	0.3	45.7	0.2	3.21	0.40	0.15	4.14	0.26
	Ap2	4.3	4.1	14.92	1.21	0.24	1.08	0.10	1.42	4.36	0.230	1.21	0.15	5.7	48.8	11.6	39.6	1.6	24.6	0.2	6.80	0.18	0.07	4.09	0.52
	B	4.2	4.0	10.09	4.68	0.11	0.54	0.36	1.01	3.03	0.120	1.43	0.19	3.9	48.4	12.9	38.7	1.5	39.4	0.2	5.18	0.22	0.06	4.21	0.24
NM-Up2	Ap	4.0	3.8	13.39	4.77	0.27	0.72	0.18	1.17	4.16	0.200	1.55	0.20	5.4	46.9	12.2	40.9	1.0	55.5	n.d.	n.d.	n.d.	n.d.	4.41	0.05
	Bt	4.1	3.8	14.69	5.52	0.24	0.72	0.10	1.06	4.01	0.190	1.33	0.20	5.4	32.9	15.4	51.7	1.5	43.8	n.d.	n.d.	n.d.	n.d.	4.02	1.17
	B1	4.3	4.0	11.74	5.11	0.18	0.72	0.18	1.08	2.45	0.140	1.29	0.17	3.1	26.7	36.3	36.9	1.1	16.9	n.d.	n.d.	n.d.	n.d.	4.30	0.11
	B2	4.2	4.1	10.97	4.71	0.15	0.90	0.18	1.23	2.30	0.120	1.34	0.10	1.4	46.3	12.3	41.4	0.6	30.8	n.d.	n.d.	n.d.	n.d.	4.15	0.54
NM-P1(0–8cm)		4.4	4.3	12.58	1.52	0.16	2.34	0.90	3.40	4.60	0.240	1.73	0.17	3.2	19.8	34.2	45.9	3.5	40.4	0.2	1.13	0.82	0.32	4.07	2.33
	2(8–23)	4.4	4.3	9.24	1.21	0.08	2.70	0.36	3.14	2.84	0.140	1.65	0.15	5.4	20.7	29.9	49.5	11.1	49.1	0.2	1.09	0.85	0.32	4.33	1.36
	3(23–37)	4.5	4.4	6.76	1.30	0.06	1.62	0.18	1.86	1.76	0.090	1.69	0.17	3.6	13.1	18.7	68.1	4.6	49.2	0.1	0.72	0.81	0.19	4.12	1.00
	4(37–80)	4.5	4.3	6.45	1.95	0.06	1.26	0.54	1.86	1.22	0.070	1.65	0.11	4.5	21.0	23.2	55.8	9.8	63.3	0.2	1.19	0.77	0.14	4.32	0.55
	5(80–100)	4.0	4.0	18.94	7.53	0.05	1.80	3.50	5.35	1.20	0.070	1.48	0.11	9.8	7.4	10.0	82.5	12.5	24.1	0.1	0.12	2.63	1.99	2.56	3.20
	Ave.	4.4	4.2	11.26	3.03	0.16	1.40	0.57	2.13	2.73	0.141	1.49	0.16	4.5	32.2	17.5	50.4	3.4	38.9	0.2	2.68	0.66	0.31	4.11	1.06

*, **: See Table 2

Table 4 Chemical, Physical, and Mineralogical Properties of Soils in Nam Luc Commune

Items*		pHw	pHK	CEC	ExH	ExK	ExCa	ExMg	ExSum	OM	TN	TK	TP	AvP	Clay	Silt	Sand	WDC	WDS	Alo	Fed	AloAld	FeoFed	PZSE	σp
Soil Name**				cmol (+) kg^{-1}						g kg^{-1}					%									cmol (+) kg^{-1}	
NL-Fr	A1	4.6	4.5	11.72	3.04	0.96	1.44	0.18	2.58	6.02	0.298	0.81	0.17	7.2	38.3	11.1	50.6	1.6	21.1	0.2	0.78	0.68	0.49	4.22	1.20
	A2	4.0	4.0	9.44	3.04	0.25	0.90	0.10	1.25	3.30	0.166	0.88	0.12	3.6	33.0	10.8	56.2	1.3	34.0	0.2	0.98	0.76	0.20	4.28	0.56
	B1	4.4	4.2	8.93	2.79	0.14	1.80	0.90	2.84	2.35	0.115	0.95	0.10	3.5	34.2	10.2	55.6	1.0	28.8	0.2	0.88	0.72	0.19	4.24	0.50
	B2	4.4	4.2	6.29	3.04	0.19	0.54	0.36	1.09	2.20	0.110	0.87	0.12	3.6	35.8	10.3	53.9	2.9	54.9	0.1	0.88	0.63	0.15	4.26	0.50
	BC	4.4	4.2	6.49	2.69	0.17	0.54	0.27	0.98	1.76	0.103	0.84	0.10	4.1	35.5	11.7	52.8	1.0	41.7	0.1	0.81	0.53	0.08	3.67	1.71
	Ave.	4.4	4.2	8.57	2.92	0.34	1.04	0.36	1.75	3.13	0.158	0.87	0.12	4.4	35.4	10.8	53.8	1.6	36.1	0.2	0.87	0.66	0.22	4.13	0.89
NL-Fa	A1	4.5	4.5	8.31	1.27	0.30	2.16	0.36	2.82	2.98	0.138	0.72	0.12	5.7	22.9	11.4	54.5	1.5	26.3	n.d.	n.d.	n.d.	n.d.	4.15	1.66
	A2	4.5	4.5	7.09	1.95	0.18	1.08	0.36	1.62	2.15	0.112	0.77	0.10	3.3	24.8	11.5	63.7	2.5	137.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d
	B	4.4	4.4	5.71	2.42	0.14	0.90	0.10	1.14	1.76	0.095	0.79	0.08	3.5	26.9	11.0	62.0	0.4	55.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
NL-C	Ap	5.4	5.4	12.00	0.00	0.45	7.74	2.16	10.35	3.52	0.169	1.08	0.12	3.5	17.2	14.1	68.7	1.6	9.7	0.1	0.52	0.94	0.24	4.17	1.24
	Ap1	4.6	4.4	11.47	0.93	0.35	2.88	2.16	5.39	2.84	0.138	0.79	0.17	3.3	28.4	16.3	55.3	1.3	23.1	n.d.	n.d.	n.d.	n.d.	4.35	0.72
	Ap2	4.5	4.3	9.60	1.67	0.28	2.88	0.36	3.52	2.84	0.137	0.78	0.17	4.1	31.6	15.2	53.2	0.3	20.2	n.d.	n.d.	n.d.	n.d.	4.19	0.57
	B1	4.5	4.3	8.71	2.14	0.18	1.44	0.72	2.34	3.82	0.192	0.87	0.15	3.4	31.9	13.5	54.7	0.7	32.8	n.d.	n.d.	n.d.	n.d.	4.33	0.57
	B2	4.5	4.4	8.92	2.14	0.14	1.44	1.26	2.84	1.47	0.106	0.82	0.15	3.0	34.6	13.9	51.4	1.2	38.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	B3	4.6	4.5	8.87	1.79	0.14	1.26	1.98	3.38	1.22	0.093	0.83	0.17	3.6	40.0	12.8	47.2	2.2	38.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
NL-P	Ap1	4.8	4.5	5.97	0.52	0.16	1.44	0.36	1.96	2.45	0.121	0.68	0.15	3.4	17.9	9.9	72.1	3.8	54.4	0.1	0.81	0.48	0.28	n.d.	n.d.
	Ap2	4.8	4.5	7.86	0.25	0.30	2.52	0.72	3.54	2.50	0.125	0.58	0.15	3.2	19.7	10.0	70.3	3.4	45.5	0.1	0.70	0.69	0.37	4.59	1.31
	AB	4.5	4.4	7.56	0.99	0.22	1.08	0.72	2.02	1.76	0.105	0.68	0.08	3.0	21.6	11.0	67.4	0.6	21.4	0.1	0.92	0.47	0.17	4.15	0.88
	B2	4.5	4.4	5.94	1.42	0.13	1.08	0.72	1.93	1.32	0.103	0.69	0.10	1.5	24.8	9.7	65.5	3.4	46.0	0.1	0.92	0.44	0.10	n.d.	n.d.
	B2	4.5	4.3	5.68	1.70	0.08	0.90	0.10	1.08	0.98	0.094	0.61	0.12	5.4	30.3	16.8	52.9	2.5	38.2	0.1	0.79	0.53	0.10	n.d.	n.d.
	B3	4.5	4.3	5.87	1.61	0.09	1.08	0.10	1.27	1.07	0.076	0.75	0.10	4.9	37.8	2.8	59.4	1.5	142.9	0.1	1.07	0.49	0.06	4.50	0.46
NL-Up	Ap1	4.6	4.2	12.03	0.40	0.56	4.50	0.90	5.96	3.62	0.162	0.87	0.12	9.2	21.5	22.2	56.3	1.6	9.4	0.1	0.89	0.82	0.21	n.d.	n.d.
	Ap2	4.6	4.5	9.52	2.17	0.32	1.44	0.18	1.94	2.89	0.137	0.95	0.10	4.9	31.6	13.0	55.3	0.6	23.9	0.1	0.39	1.74	0.48	n.d.	n.d.
	AB	4.5	4.3	8.42	2.69	0.18	1.08	1.08	2.34	1.96	0.101	0.96	0.08	4.7	37.1	12.6	50.2	1.7	42.6	0.1	1.62	0.41	0.09	n.d.	n.d.
	B1	4.0	4.0	8.60	2.32	0.12	1.62	0.72	2.46	1.50	0.080	0.91	0.08	3.9	43.8	12.2	44.0	1.0	38.7	0.1	3.13	0.22	0.03	4.32	0.33
	B2	4.5	4.3	10.94	1.98	0.13	2.70	3.14	5.97	0.80	0.069	0.89	0.09	3.9	31.8	12.5	55.7	2.3	15.9	0.1	1.28	0.63	0.06	4.49	0.46
	Ave.	4.6	4.4	8.45	1.52	0.22	2.06	0.91	3.19	2.17	0.118	0.80	0.12	4.1	28.8	12.6	58.0	1.7	43.0	0.1	1.09	0.66	0.18	4.32	0.82

*, **: See Table 2

the foothill commune show the lowest value of CEC with the lowest amount of organic matter (OM), especially in the crop field. The amount of Fed is lower than the other communes. Therefore, the weathered soil from granite in the foothill commune could be considered less fertile due to the acidic nature of the parent materials. Even though the soil fertility in the foothill commune was the lowest, the major agricultural practice was shifting cultivation, the least intensive agricultural method in the mountainous region. This disadvantage is thought to be compensated by the relatively higher temperature due to the lowest elevation among three communes, as described in the previous section.

The ratios for water dispersible clay to completely dispersed clay (WDC) were extremely low throughout the sites examined even though the clay content varied greatly among the communes and within each commune. Among them, WDC was the lowest in the hilltop commune (maximum value of 3.6 in the subsoil of the forest). Only the paddy field of the mid-slope commune (NM-P) showed a little higher value than the others. This might be proof that the clays with a higher WDC were accumulated in the paddy field in the valley, since clay fractions with a high dispersibility were prone to be eroded in the course of heavy rain and moved away from the slope land down to the paddy field.

Clay mineral composition in the mid-slope commune (Table 5) showed the presence of hydroxyl-interlayered vermiculite (HIV) together with kaolins followed by illite. The HIV is one of the resistible clays against water dispersion. Among the clay minerals found here, illite is most easily dispersed [Itami and Kyuma 1995]. However, the relative abundance of illite for all soils examined was not significantly high. Thus, soil erodibility in this region was not considered high even though the slope in the field was steep enough for erosion. In addition, the value of pH measured in water (pHw) was low enough to prevent soil dispersion, which allowed exchangeable Al ions to neutralize the negative charge of clays arising from isomorphous substitution [*ibid.*]. Larger negative charge induces more repulsion of

Table 5 Clay Mineral Composition in Each Commune

Site	Horizon	Clay Minerals*						
		Fe-Ch	HIV	It	Kt	Gb	Gt	Qz
LTN-Fr2	A	±	++	+	++	++	±	+
	B2	++	++	±	+	+	±	+
LTN-Up	Ap		+++		+	++	+	+
	B2	±	++		+	++	+	+
NM-Fr	A		+	+	+	++	±	++
	B		++	+	++	+	+	+
NM-Up1	Ap1		++	+	++	+	+	+
	B		++	+	++	+	+	+
NL-Fr	A		+	±	+++	+	±	+
	B2		+	±	+++	+	±	+
NL-Up	Ap		++	+	++	±	±	+
	B1		+	+	++	+	±	+

*Fe-Ch, Fe-chrolite; HIV, hydroxyl-interlayered vermiculite; It, Illite; Kt, Kaolins; Gb, Gibbsite; Gt, Goethite; Qz, Quartz

±, 0–5%; +, 5–20%; ++, 20–40%; +++, 40–60%

clay particles, and leads to more dispersion of clays.

Only the subsurface layer of forest soils in the hilltop commune retained a significant amount of Fe-chrolite and HIV, and lesser amounts of kaolins. Since gibbsite is accumulated as a proof of the presence of abundant exchangeable aluminum reflecting highly acidic soil properties, the soils in the hilltop commune are potentially more acidic than others. Also, soils here were not ultimately weathered as mentioned before. A cooler climate due to higher elevation would keep the soils younger against severe weathering. On the other hand, in the mid-slope and foothill communes, relative abundance of kaolins was higher than in hilltop commune. Since kaolins were one of the most inactive clays physico-chemically (low activity clay) with the other constituents of soils, CEC values of mid-slope and foothill communes were also lower than those of the hilltop commune. Therefore, based on the clay mineral composition, cooler climate in the higher elevation was most influential factor for soil genesis in the mountainous region under the subtropical climate.

Table 6 summarizes the results of correlation analysis using soil parameters in Tables 2 to 4 on chemical, physical, and mineralogical properties. The pHw value was positively correlated with alkaline earth elements (ExCa and ExMg) and negatively with acidity (ExH), organic matter (OM and TN), clay content, and amorphous aluminum content (Alo). This trend was commonly found in natural soils. These findings indicate that agricultural practices, including fertilization did not affect the soil properties greatly. CEC was correlated positively with amount of nutrients held by soils (ExSum and ExCa), organic matter (OM and TN) and available phosphorus (AvP), accumulation of Al and Fe (Alo and Fed). Although the amount of crystallized clay minerals with permanent charges could not be quantified, the magnitude of permanent negative charge could be estimated by that of σp. The magnitude of σp could be considered as the actual amount of permanent negative charge revealed at the field condition [Sakurai *et al*. 1988]. The σp value reflects the amount of permanent negative charge and also OM [Sakurai *et al*. 1989]. Thus the linear correlation

Table 6 Major Correlations among Soil Properties with a Significant Correlation Coefficient

		1% Level	5% Level
pHw	Positive	ExCa, ExMg, TK, Silt, PZSE	
	Negative	ExH, OM, TN, Clay, Alo	AvP
CEC	Positive	ExSum, ExCa, OM, TN, AvP, Alo, Fed, σp	ExH
	Negative	Sand, WDS	
WDC	Positive	Sand, Alo/Ald, Feo/Fed	TK, ExMg
	Negative	Clay	ExK, Fed
PZSE	Positive	pHw, TK, Silt	Fed
	Negative	OM, ExH, AvP, Alo/Ald, Feo/Fed, σp	
σp	Positive	CEC, ExCa, ExMg, ExSum	
	Negative	PZSE	

between σp and OM is not always high. Since most of the nutritional elements such as Ca, Mg, K, and NH_4 are retained by the permanent negative charge, high correlation between CEC and Fe or Al oxides and hydroxides shows the relative importance of them as sources of variable charge. This is one of the proofs for the dominance of strongly weathered soils [*ibid.*]. Positive correlation of the 5 percent significant level between CEC and exchangeable H (ExH) indicated the presence of permanent negative charges arising from crystalline phyllosilicates such as HIV and illite in Table 5. Nonetheless, the dominance of crystalline phyllosilicates could not be found, and therefore, strongly weathered nature of the soils here controls the nutrient retention. Although the WDC was correlated with some soil properties, WDC value itself was quite small and less important. The value of PZSE was correlated negatively with OM content, the magnitude of permanent negative charge, exchangeable aluminum, and crystalline Si oxides and positively with oxides and hydroxides of Al and Fe [Sakurai 1990]. Since the Alo/Ald and Feo/Fed become lower upon weathering as mentioned before, negative correlation between PZSE and these two ratios indicate that the soils here were in the various weathered condition. In addition, PZSE values around 4.0–4.5 and Feo/Fed values more than 0.1 indicate that the soils studied were in the process of strong weathering but had not yet reached the level of the ultimately weathered soils.

IV Conclusions

IV–1 *Fertility*

Soil pH was lower than 5.0 showing strong acidity. Only maize plantations showed a higher soil pH of more than 5.0 probably due to liming. CEC values in the foothill commune and some part of mid-slope commune were around 12 (cmol(+) kg^{-1}) which is slightly higher than the definition of soils with low activity clay (10 cmol(+) kg^{-1}). Organic matter decreased after cultivation. Although the source of organic manure is scarce throughout the area, it is necessary to amend the crop field by an addition of organic fertilizer, such as manure.

IV–2 *Weathering*

The PZSE values of all soils are mostly between 4.0 and 4.5, and σp values of subsoils are lower than 1.0 (cmol(+) kg^{-1}). Activity ratio of Al (Alo/Ald) is higher at the foothill commune than the hilltop and mid-slope communes, while that of Fe shows no significant differences among sites. Weathering in the past seemed to be strongest at the mid-slope commune compared with the hilltop commune at the higher altitude, while the foothill commune would be more affected by more addition of organic materials compared with the other two communes due to warmer climate currently, and seemed to be rejuvenated. Clay mineralogy of three communes supported this supposition.

Considering these observations, though weathering status of the soils at the three communes was similar with each other, weathering condition at present could be considered to be deepest in the mid-slope commune, followed by the hilltop communes, then the foothill commune.

IV–3 *Impact of Agricultural Practices on Soil Properties*

Soils of lowland paddy fields in three communes contained more clay particles with a higher negative charge density (represented as σp value) probably due to an accumulation of clays eroded from the upper part of the slope. Maize cultivation accompanied with liming improved soil chemical properties to some extents. On the other hand, the soil weathering conditions of each area is little affected by current land use. Rather, it is affected by the local climatic condition.

The clay dispersion ratio of all the sites studied was very low. In addition, clay dispersion ratio and clay content were not different among different land uses. This means soil erosion would not seem to have a strong impact on farm fields under the current farming systems of the three communes. However, activity ratios of Al and Fe (Alo/Ald and Feo/Fed) became lower after cultivation, and therefore, in the long term slight but continuous erosion (during i.e. 20 years) might have occurred to reduce the activity of soils.

Thus, it could be concluded that the difference in land use and farming system is mostly dependent upon the current temperature, which changes along the elevation. Soil properties, both fertility and weathered status, were generally at the strongly weathered level, but not at the ultimately weathered level. Terracing at the highest altitude (the hilltop commune), contour planting at the middle altitude (the mid-slope commune), and shifting cultivation at the lowest altitude (the foothill commune) can be considered as a rational choice of the local farmers, in terms of local condicions. However, even at the lowest part of Bac Ha district like the foothill commune people should shift to the contour planting or terracing in the near future to support the life standard of the village.

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Soil Fertility and Farming Systems in a Slash and Burn Cultivation Area of Northern Laos

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Abstract

The physico-chemical properties of the soil in shifting cultivation fields in Xiang Ngeun district, Luang Phabang province were investigated in order to provide a basis for developing an agricultural system that will be sustainable under higher population pressure on the land and increased demand to engage in intensive farming. The soils in the study area have reasonably high contents of soil nutrients despite being on erosion-prone sloping land. Soil fertility status may not be fully restored even when the length of fallow is 10 years. The nutrients accumulated in the soil during fallow period are small compared with the nutrients supplied from the ash input when the biomass is burned so that soil nutrients were found not to be exhausted after a single year of cultivation. However, the density of weeds increases as the fallow period is shortened. Therefore, fallow plays an important role in weed control during the cropping period. These findings suggest that an agroforestry system that combines crop cultivation with paper mulberry production could be a sustainable farming system for short-fallow shifting cultivation. To be acceptable to the farmers, this agroforestry system must be effective both in controlling weeds and in generating income for the shifting cultivators.

Keywords: agroforestry system, fallow management, Northern Laos, paper mulberry, slash and burn cultivation, soil erosion, soil fertility, weed control

I Introduction

Slash-and-burn farming (also called shifting cultivation or swidden agriculture) is a major land-use practice in the hilly areas of Laos [Fujisaka 1991; Lao PDR, State Statistical Center 1990]. Most of the forests within these areas have already experienced slash-and-burn prac-

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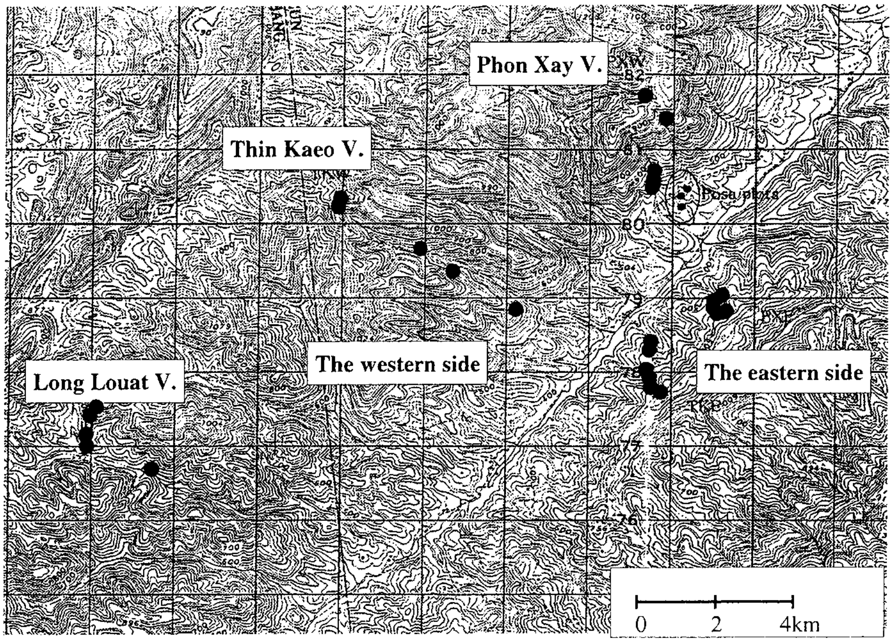
tices several times. Roder *et al.* [1994] reported that the combined effects of increased population density and government policies limiting access to land have reduced fallow periods from about 40 years in 1950 to only 5 years in 1992. The Government of Laos aims to reduce and stabilize slash-and-burn cultivation through a gradual expansion of other production systems such as permanent cash crop production, and wood and fruit production. The forest law of 1996 states that an individual family is to be allocated an area of no more than three hectares. In addition, the clearing of new plots in well-developed natural forest or fallow forest is also prohibited. This forces farmers to do more intensive farming on existing fields.

Although there have already been several studies of slash-and-burn farming in Laos [e.g. Nabong Technical Meeting 1994], the sustainability of intensive farming systems is not clear, partly because little information on soils in Laos is available at this stage. Therefore, in the research reported here, we investigated soil physico-chemical properties in shifting cultivation fields to provide a basis for developing a practical and sustainable agricultural system. We also propose a model system for sustainable intensification of farming systems in this region.

II　Description of the Study Area

The study area is situated in Nam Khan Watershed in Xiang Ngeun district, Luang Phabang province about 25 km southeast of Luang Phabang city. The Nam Khan River runs through



● soil sampling point

Fig. 1　Map of the Study Area in Xiang Ngeun District, Luang Phabang Province, Lao PDR

Table 1 General Information of the Villages Studied

Village Name	Thin Kaeo	Phon Xai	Long Lonat
Year of establishment	Old village	1972	1991
Population (household)	900 (145)	634 (102)	229 (40)
Lao Loum	5 (1)	112 (21)	14 (2)
Lao Thung	645 (110)	552 (81)	184 (35)
Lao Soung	240 (34)	0 (0)	31 (3)
Total area (ha)	1,484	1,300	3,300
Agricultural land (ha)			58.9
Swidden field	123	103 (fallow 120)	30.1(only rice field)
Paddy field	15.5	17.7	3
dry season	no data	12.8	3
upland field	2.7	51.3	23.3
Farming style (household)			
Only shifting cultivation	119	75	32
Only paddy field	5	6	1
Paddy + Swidden field	20	21	4
Paddy field dry season	23	22	5

the district from southwest to northeast. Its total watershed area is 170.8 km^2. The mean air temperature is 26.2˚C, and the annual precipitation and number of rainy days were 1,050 mm and 103 days in 1998, and 1,226 mm and 122 days in 1999, respectively. Precipitation occurs mostly from May to October.

Thin Kaeo village (TK), Phon Xay village (PX) and Long Louat village (LL) were selected for the present study (Fig. 1). General information from these three villages obtained in interviews with the village headmen is summarized in Table 1. Land-forest allocation to households was implemented in 1996, 1998, and 1997, in TK, PX, and LL, respectively. TK village is an old village. PX and LL had been resettled in 1972 and 1991, respectively. Residents are mostly Lao Thung people who engage in slash-and-burn cultivation. The percentage of the households engaged in slash-and-burn cultivation is 82 percent in TK, 73 percent in PX and 80 percent in LL. Total area of LL is very large because it includes the territory of the previous settlement, although LL villagers hardly use this land as it is very far from the present settlement.

The average cropped area each year including upland rice per household is about one ha. On average there are six people and two laborers in a household. The land-forest allocation gave each household from one to four plots with a total field area of one to five ha according to the number of laborers in a household. Households that possessed paddy fields received only one upland field plot so they must cultivate the same plot every year.

According to the TK village headman, yields of upland rice had become lower than before so that many villagers grew Job's tears instead of upland rice in 1999. However, the price of Job's tears declined sharply in 2000. The percentage of households suffering from a rice shortage will probably amount to about 70 percent in 2000, up from 40 percent in 1999. The village headman of PX said that it was difficult for them to plant lowland rice in the dry season because the amount of water in the tributary has decreased in the past five years. He thought that this was because of a decrease in forest area caused by slash-and-burn cultivation, although he had no empirical basis for this belief.

He believes that they have to reallocate land among villagers in order to protect forestland. Chikami and Komoto [1999] reported that traditional institutions of forest management are weak in newly established villages in central Laos, which may cause degradation of forest. We believe that this is not the case in the villages of our study because these communities all have rather long histories even before the re-settlement. Instead, interviews with villagers revealed that they understood the need for proper land-forest allocation in order to accomplish sound forest management. Problems regarding the shortage of cultivable land, degradation of soil, and decrease in crop yields have arisen after the implementation of land-forest allocation in 1996.

III　Methods for Evaluation of Soil Fertility

III–1　*Soil Sampling*

Based on interviews with farmers on land use history, we selected 27 soil-sampling sites (10 in PX, 12 in TK and 5 in LL) in plots with different land use histories (Fig. 1). The land use history of the sampling sites is summarized in Table 2. Site name stands for the year of last fallow or cultivation in 1999. Four sites are in natural forest, 4 sites in long fallow fields more than 10 years, 9 sites in short fallow fields less than 10 years, and 10 sites in currently cultivated fields. Most of the sites had been under fallow for from 4 to 6 years before cultivation, but TKW-C1 was fallow for more than 10 years before cultivation, and TKE-C1 was fallow for 2 years before cultivation. The slope gradient of most sites ranged from 10˚ to 30˚ and their elevation ranged from 600 m to 1,100 m above mean sea level. Soil samples were collected from the surface 0–5 cm layer and the subsurface 20–25 cm layer. Soil sampling was carried out three times: before burning (February), after planting (July) and after harvest (October) in 2000. Five samples were collected from every layer and mixed into one composite sample. Two or three undisturbed soil samples were also collected by a 100 ml core sampler and used for water permeability analysis.

The soil profile was described at five sites: TKE-Fa20 (the eastern side of Nam Khan River, the 20-year fallow forest in TK village), PXE-C1 (the 1-year cultivated field in PX), PXW-NF (the western side of the river, the natural forest in PX), LLW-Fa26 (the 26-year fallow forest in LL village), and TKW-C3 (the 3-year cultivated field in TK village). Soil samples were collected at depths of 0, 5, 10, 20, 40, 60 and 80 cm. This survey was carried out in February and October 2000.

III–2　*Analytical Methods*

Analytical items of soil property included pH, electrical conductivity (EC), exchangeable cations (Ca, Mg, K and Na), cation exchangeable capacity (CEC), total carbon (T-C), total nitrogen (T-N) and available phosphorus (AvP). We added particle size distribution, sesquioxides content (Al, Fe and Si), clay mineral composition, point of zero salt effect (PZSE) and σp for the samples collected from the soil profiles.

Soil pH was measured under the condition that soil to water ratio is 5 g to 25 ml. EC was measured before pH measurement. Exchangeable cations (Ca, Mg, K and Na) were extracted with 1 M-ammonium acetate (pH 7.0) under the condition that soil to solution ratio is

Table 2 Sample Name, Slope Direction and Gradient, and Land Use History

Sample Name		Slope Direction and Gradient	Land Use History Year										
			90	91	92	93	94	95	96	97	98	99	2K
PXE	NF	N70° W, 35°											
	Fa5	S80° E, 18°				R	R						
	Fa2	S80° E, 17°							R	R			
	C1	S80° E, 21°					R					R	
	C3	N40° E, 24°			R					R	R	J	
PXW	NF	S30° W, 30°											
	Fa15	S50° E, 26°											
	Fa3	S80° E, 25°							R				
	C1	N30° E, 32°			R							R	
	C4	E, 33°							R	R	J	J	
TKE	Fa20	N20° W, 13°											
	Fa8	N20° W, 34°		R									
	Fa4	N40° W, 28°					R	R					
	Fa2	N45° W, 15°							R	R			
	C1	N45° W, 13°						R	R			R	
	C3	N80° W, 13°		R	R					R	R	J	
TKW	NF	S20° E, 19°											
	Fa30	S34° W, 23°											R
	Fa6	S11° E, 18°				R							R
	C1	S34° W, 23°										R	R
	C2	N61° E, 36°	R	R							R	R	
	C3	N16° E, 32°	R							R	R	J	
LLW	NF	N10° E, 11°											
	Fa26	S75° W, 11°											R
	Fa6	S40° W, 20°				R							R
	Fa2	S30° E, 5°				R					R		
	C2	S75° E, 17°		R							R	R	R

Notes: PXE, the eastern side of the river in Phon Xay village; PXW, the western side of the river in Phon Xay village; NF, natural forest; Fa, fallow field; C, cultivated field.
The figure after letter represents fallow or cultivated period (yr).
R, upland rice; J, Job's tears; fallow

5 g to 25 ml by reciprocal shaking followed by centrifugation. The amounts of Ca, Mg and K were determined by atomic adsorption spectrophotometry, and that of Na by flame photometry (Shimadzu, AA-610S). Then, the residue was once washed with deionized water and twice with 990 g l^{-1} CH_3CH_2OH to remove the excess salt. The adsorbed ammonium was exchanged twice with 100 g l^{-1}-NaCl solution through reciprocal shaking for 1 hour followed by centrifugation for 10 minutes at 179 G. The ammonium ion content in the supernatant was determined by the titration method after Kjeldahl distillation and taken as CEC. T-C and T-N were determined by the dry combustion method with NC-Analyzer (Sumitomo, Sumigraph NC-80). AvP was extracted with an extracting solution containing 0.03 M NH_4F and 0.1 M HCl, followed by reciprocal shaking for 1 minute under the condition that soil to solution ratio is 1 to 20 (Bray-II method), and colorimetrically analyzed for Av-P using a spectrophotometer at 710 nm.

Particle size distribution for silt and clay fractions was determined by the pipette sampling method after wet decomposition of organic matter with 60 g l^{-1} of hydrogen peroxide and dispersion with the addition of 1 M NaOH to raise the solution pH to 9.5. Particle size distribution for fine sand and coarse sand fractions was determined by sieving. Al, Fe and Si oxides were extracted twice with an acid ammonium oxalate solution (0.2 M, pH 3.0) by reciprocal shaking in the dark for 1 hour [Mckeague and Day 1966], under the condition that soil to solution ratio is 1 to 25. They were extracted twice with a citrate-bicarbonate mixed solution buffered at pH 7.3 with the addition of sodium dithionite for 15 minutes at 75 to 80 degree centigrade [Mehra and Jackson 1960], using soil to solution ratio of 1 to 100. Al, Fe and Si contents in the extract were designated as Alo, Feo and Sio for the former extractant, and Ald, Fed and Sid for the latter, respectively. The contents of all the cations were determined using a sequential plasma spectrometer (Shimazu, ICPS-1000IV). Clay minerals were identified by the X-ray diffraction method (Shimazu, XD-D1w). The specimens of K- and Mg-saturated clay with parallel orientation were prepared by the alternate saturation technique using acetate and chloride salts [Jackson 1969]. X-ray diffractogram was taken for the air-dried K-saturated clay, then for the clay heated to 100, 350, 550 degree centigrade for 2 hours successively as well as for the air-dried Mg-saturated clay and for the clay treated with 10 percent glycerol. PZSE (designated as ZPC in their paper) and σp value (residual charge at PZSE) were determined by the modified salt titration (STPT) method [Sakurai *et al*. 1988].

IV　Results and Discussion

IV–1　*Morphological Properties*

The morphological properties of five soil pits for profile description are given in Table 3. Topographically, PXW-NF, LLW-Fa26 and PXE-C1 are located in the upper part of the hills, TKW-C3 in the middle part of the hills, and TKE-Fa20 in the middle part of the high terrace.

The parent materials are limestone and shale.

We could observe several differences between the western and eastern sides of the Nam Khan River. The western side has steeper slopes with more gravel in the very shallow soil layer, while the western side has the A and C profiles, except TKW-C3 which has a thin Bt layer. TKE-Fa20, on the eastern side, has the A, Bt and C profiles. The western side does not show a developed soil structure unlike the eastern side. These differences reflect the differences in topography and are not caused by the effect of burning. The profiles are classified as Inceptisols (PXW-NF and LLW-Fa26) and Alfisols (TKW-C3) on the western side and Ultisols (TKE-Fa20 and PXE-C1) on the eastern side [Soil Survey Staff 1987].

The soil texture is light clay to heavy clay. The surface layer has a medium organic matter content but it is very thin. According to Kyuma *et al*. [1985] after burning the color of soil profile was entirely different and Kadir *et al*. [2001] reported that soils at burnt areas showed a lighter A horizon than those of unburned areas. However, we could not observe differences in soil color between forest and cultivated lands. This may be because the accumulation of organic matter is weak during the fallow period.

IV–2 *Physico-chemical and Mineralogical Properties of Soil from the Pedons*

Table 4 shows sesquioxides content, charge characteristics and clay mineral composition of the soils in the profile description sites. There were no remarkable differences in sesquioxides content and charge characteristics between the western and eastern sides.

Fed value ranged between 20.0 to 45.0 g kg^{-1}. Higher values of crystalline oxides (Ald and Fed) indicate relative accumulation of oxidized Al and Fe associated with weathering. The activity ratios of Fe (Feo/Fed) and Al (Alo/Ald) become higher with the progress of weathering. Feo/Fed of the surface layer of LLW-Fa26, TKW-C3 and TKE-Fa20 are higher than 0.1, reflecting a rejuvenated condition by the addition of organic matter. PXW-NF and PXE-C1 showed lower Feo/Fed even at the surface layer, although Alo/Ald in PXW-NF were slightly higher than the other sites.

PZSE is mostly below four. According to Sakurai *et al*. [1989], PZSE shifted toward lower value by the presence of 2 :1 type clay minerals, organic matter and/or exchangeable Al. PZSE at the surface layer is generally low due to higher organic matter contents. The surface layer of PXW-NF and TKW-C3 showed higher PZSE value than the subsurface layers. This could be attributed to the presence of higher amorphous oxides (Alo and Feo) and exchangeable Ca and Mg (appendix) at the surface layer [*ibid*.; Sakurai *et al*. 1996]. σp is the remaining charge at PZSE, and both organic and mineral components capable of adsorbing H^+ or OH^- at PZSE contribute to the value of σp [Sakurai 1990]. σp is lower in a deeper horizon. σp of deeper layers at LLW-Fa26, TKE-Fa20 and PXE-C1 were below 1, and it ranged between 0.36 to 1.31 at TKE-Fa20. Therefore, σp is the lowest at TKE-Fa20 and the highest at PXW-NF and TKW-C3.

Illite, 2:1 type clay mineral, was the dominant clay mineral species across the sites. Kaolinite and quartz also showed higher contents. Hydroxy-interlayered vermiculite (HIV)

Table 3 Morphological Characteristics of the Soils Studied

	Horizon	Depth (cm)	Color	Texture	Structure[a]	Boundary[b]	Consistence[c]	Rock fragment[d] (size cm)	Remark
PXW-NF	A	0–12	7.5YR3/2	LiC	w vf gr	cw	ss/p	m sbk st (1–2)	
	AC	–25	5YR4/3	LiC	1	gi	ss/p	a sbk st(2–3)	
	C1	–55	5YR4/4	LiC	1	gi	ss/p	a sbk st(2–3)	
	C2	–55+	5YR4/4	LiC	1		ss/p	d sbk st(10–15)	
LLW-Fa26	A	0–5	7.5YR4/2	Lic	w vf sbk	aw	ss/p		
	AC	–15	7.5YR5/4	LiC	w vf sbk	cw	s/p	c sbk sl(0.2–0.5)	
	C1	–20/25	7.5YR4/4	LiC	1	ci	s/p	m abk st(2–3)	
	C2(GL)	–45	7.5YR4/6	LiC	1	di	s/p	d sbk st(3), sl(0.5)	
	R	–45+	5YR4/6	LiC	1		s/p	d sbk st(5–10)	
TKW-C3	A	0–8	10YR3/3	LiC	m vf sbk	cw	s/p	f sbk sl(1)	
	Bt	–15	7.5YR4/3	HC	s f sbk	cs	s/vp	c sbk w(3)	clay cutan, chacol
	C1	–35	7.5YR5/6	HC	1	gw	s/vp	a abk w(3–7)	clay cutan
	C2	–80+	10YR5/6	HC	1		s/vp	d sbk st	clay cutan
TKE-Fa20	A	0–11	10YR3/3	LiC	w vf gr	cw	ss/p		
	Bt1	–36	7.5YR5/6	LiC	s c sbk	gi	ss/p	c sbk w(1–2)	many mottling, clay cutan, charcoal
	Bt2	–87	5YR5/8	HC	s c sbk	as	s/p	a sbk w(2–3)	clay cutan, chacoal
	C	–100+	2.5YR4/8	HC	1		ss/p	d sbk st stone	
PXE-C1	A	0–12	7.5YR3/2	HC	m f sbk	cs	s/vp	f sbk w(1)	
	AB	–25	7.5YR4/4	HC	m m sbk	cw	s/vp	f sbk w(2–3)	clay cutan, chacol
	Bt1	–50	7.5YR4/6	HC	w f sbk	gs	s/vp	c sbk w(5)	clay cutan, chacol
	Bt2	–100+	5YR4/6	HC	w f sbk		s/vp	c sbk w(5)	clay cutan

[a] Abbreviations used for soil structure. Grade: 1, structureless; w, weak; m, moderate; s, strong. Class: vf, very fine; f, fine; m, medium; c, coarse. Type: sbk, subangular blocky; gr, granular

[b] Abbreviations used for boundary. Distinctness: c, clear; g, gradual; a, abrupt; d, diffuse. Topography: s, smooth; w, wavy; i, irregular

[c] Abbreviations used for Consistence. Stickiness: ss, slightly sticky; s, sticky. Plasticity: p, plastic; vp, very plastic

[d] Abbreviations used for rock fragment. Abundance: c, common; m, many; a, abundant; d, dominant. Shape: sbk, subangular; abk, angular. Weathering: sl, slightly weathered; w, weathered; st, storongly weathered

Table 4 Sesquioxides Content, Charge Characteristics and Clay Mineral Composition of the Soils in the Pedons

Sample	Depth (cm)	Alo	Feo	Sio	Ald	Fed	Sid	Alo/Ald	Feo/Fed	σp	PZSE	Clay Mineral Composition				Soil Fraction		
		——— ($g\ kg^{-1}$) ———								$cmol\ kg^{-1}$		It	Kt	Qz	HIV	Clay	Silt %	Sand
The western side of the river																		
PXW-NF	0–5	1.13	1.94	0.16	2.22	34.17	2.80	0.51	0.06	4.77	5.34	++++	+	+	–	27.7	31.3	41.0
	5–10	1.21	2.05	0.13	2.37	33.37	2.18	0.51	0.06	3.94	5.86	+++	+	++	–	27.9	26.8	45.3
	10–15	1.18	1.86	0.10	2.36	36.12	1.76	0.50	0.05	3.87	4.84	+++	+	++	–	28.5	26.4	45.1
	20–25	1.15	1.68	0.08	2.70	45.05	1.99	0.43	0.04	3.99	3.38	+++	+	++	–	26.8	25.6	47.6
	40–45	1.01	1.56	0.08	2.59	35.98	1.80	0.39	0.04	4.06	1.12	++++	+	+	–	26.4	25.2	48.4
	60–65	0.95	1.59	0.08	2.31	36.44	1.58	0.41	0.04	4.04	1.11	+++	++	+	–	26.0	24.4	49.6
	80–85	0.91	1.52	0.09	2.48	38.78	2.05	0.37	0.04	4.00	1.27	++++	++	+	–	29.0	24.8	46.1
LLW-Fa26	0–5	1.38	4.07	0.13	3.01	19.98	1.84	0.46	0.20	3.66	3.33	++	++	+++	+	31.8	26.8	41.4
	5–10	1.25	3.10	0.07	3.18	22.03	0.91	0.39	0.14	3.93	1.28	++	++	++	+	39.0	28.8	32.2
	10–15	1.23	2.93	0.07	3.41	24.35	0.76	0.36	0.12	3.93	1.12	++	+	+++	+	38.9	28.9	32.2
	20–25	0.93	1.90	0.05	3.33	25.85	0.71	0.28	0.07	3.91	0.99	++	++	++	+	34.3	21.1	44.6
	40–45	1.08	1.09	0.09	4.14	33.91	0.80	0.26	0.03	4.05	0.56	+++	++	+	+	37.6	14.4	48.0
	60–65	0.94	0.79	0.09	3.66	30.09	0.82	0.26	0.03	4.11	0.43	++	++	+	+	32.8	15.4	51.8
	80–85	1.29	1.08	0.10	4.62	38.38	0.85	0.28	0.03	4.04	0.45	++	++	+	+	50.1	21.4	28.5
TKW-C3	0–5	0.82	4.13	0.39	2.43	32.08	2.20	0.34	0.13	3.47	10.55	++	++	+	+	40.2	36.6	23.2
	5–10	0.69	3.59	0.21	2.55	33.80	1.43	0.27	0.11	3.81	5.08	++	++	++	+	45.2	34.6	20.2
	20–25	0.61	2.42	0.11	2.55	34.69	1.18	0.24	0.07	4.09	2.74	++	++	++	+	48.0	35.3	16.7
	40–45	0.52	0.89	0.08	2.48	32.54	0.98	0.21	0.03	3.56	3.85	++	+	++	+	51.6	30.3	18.1
	60–65	0.54	0.91	0.08	2.57	35.25	0.99	0.21	0.03	3.51	3.77	++	++	++	+	52.2	30.9	16.9
	80–85	0.51	0.95	0.09	2.40	31.87	1.09	0.21	0.03	3.66	3.24	++	++	++	+	52.6	27.4	20.0
The eastern side of the river																		
TKE-Fa20	0–5	1.17	2.92	0.07	3.37	21.22	1.72	0.35	0.14	3.80	1.31	+++	++	+	–	41.6	40.6	17.8
	5–10	1.26	2.59	0.09	3.64	23.65	1.12	0.34	0.11	3.83	0.86	+++	++	+	–	43.2	40.2	16.6
	10–15	1.01	2.18	0.07	3.80	23.62	0.91	0.27	0.09	3.80	0.90	+++	++	+	–	44.5	39.7	15.8
	20–25	1.03	1.76	0.07	3.86	24.30	0.55	0.27	0.07	3.88	1.02	+++	++	++	–	49.7	36.4	13.9
	40–45	1.13	1.58	0.07	4.69	31.52	0.53	0.24	0.05	4.01	0.45	+++	++	++	–	57.4	30.9	11.7
	60–65	1.09	1.26	0.08	5.06	32.30	0.40	0.22	0.04	4.03	0.43	+++	++	+	–	60.2	28.4	11.4
	80–85	1.15	1.22	0.09	5.40	33.80	0.61	0.21	0.04	4.08	0.36	++	++	++	–	63.0	25.3	11.7
PXE-C1	0–5	1.45	1.79	0.10	3.78	25.54	1.53	0.38	0.07	3.68	4.48	+++	+++	–	–	47.2	33.2	19.6
	5–10	1.45	0.05	1.67	3.87	27.62	1.19	0.38	0.00	3.67	2.69	+++	+++	+	–	52.1	31.5	16.4
	20–25	1.47	2.16	0.08	4.42	30.77	0.96	0.33	0.07	4.05	1.21	+++	+++	+	–	55.0	30.1	14.9
	40–45	1.39	1.66	0.07	4.58	30.30	0.79	0.30	0.05	4.02	0.83	+++	+++	+	–	57.7	29.5	12.8
	60–65	1.21	1.57	0.07	4.47	31.56	0.75	0.27	0.05	4.04	0.83	+++	+++	+	–	58.9	25.1	16.0
	80–85	1.12	1.55	0.07	4.52	32.48	0.72	0.25	0.05	4.04	0.84	+++	+++	+	–	62.4	26.5	11.1

Notes: –, 0–5%; +, 5–20%; ++, 20–40%; +++, 40–60%; ++++, 60–80%

It, Illite; Kt, Kaolinite; Qz, Quartz; HIV, Hidroxy-interlayered vermiculite was found at LLW-Fa26 and TKW-C3. HIV is one of the highly erodible clay minerals, and soils containing HIV are not strongly weathered. The clay contents at PXW-NF decreased slightly with depth, but increased with depth at other sites. This indicates that erosion by rainwater quickly removed clay at the surface layer once the vegetation was cleared.

IV–3 *Relationship between Soil Chemical Properties and Land Use*

The soil chemical properties of pH, AvP, exchangeable Al, Ca, Mg, Na and K, CEC, T-C, and T-N at the depth of 0–5 cm and 20–25 cm were plotted against land use history in Fig. 2. Both layers showed a similar tendency, though those of the depth of 0–5 cm are slightly lower than that of the depth of 20–25 cm. Therefore, we will mainly discuss the data of the depth of 0–5 cm.

The values of pH were slightly higher on the western side than on the eastern side because of the input of limestone materials from the upper toposequence in the western side. The pH increases with an increase in fallow period within the first 10 years probably due to the accumulation of alkaline materials during fallow period and during cultivation periods due to the deposition of ash. The pH values, however, decreased after 10 years fallow, possibly because of the severe degradation of these fields before being abandoned. In other words, farmers did not utilize these plots for many years because the soil properties were too poor to cultivate continuously. This resulted in long fallow. Tanaka *et al.* [1997] reported that the soils under continuous cropping and fallow forest were more acidic than newly reclaimed soils of slash-and-burn cultivation. The experimental findings of Kyuma *et al.* [1985] showed higher pH value after 2 years cultivation than before cultivation. Our findings coincide with these observations.

Previous studies also described the decrease in exchangeable Al after burning [Tanaka *et al.* 1997; Kyuma *et al.* 1985; Tulaphitak *et al.* 1985]. However, the amount of exchangeable Al was high even at the cultivated field on the eastern side. The higher amount of Ca corresponds to the higher pH value. It is slightly higher on the western side due to the influence of the eroded materials from the limestone range. The values increased with the length of cultivation and fallow periods up to 10 years fallow. The distribution pattern of exchangeable Mg showed a similar trend with exchangeable Ca. Exchangeable K and Na, however, did not show any relationships with cultivation and fallow periods. The amount of exchangeable Na showed a slightly higher value in the eastern side than in the western side. According to Jordan [1987], Ca, Mg and K decreased rapidly after abandonment because soil erosion was accelerated. This observation does not coincide with our results probably because soil loss is not so serious in our sites due to the high clay contents. According to the technical report of Northern Agriculture and Forestry Research Center (personal communication), soil erosion loss in an upland rice field with 25–30 percent slope near the study area was annually 8.62 t ha^{-1}. This can be converted to 0.862 mm/year in thickness provided that the bulk density is 1.0 g cm^{-3}. High contents of exchangeable cations compared to strongly weathered soils elsewhere in the tropics are thought to result in low amount of soil erosion [Kyuma *et*

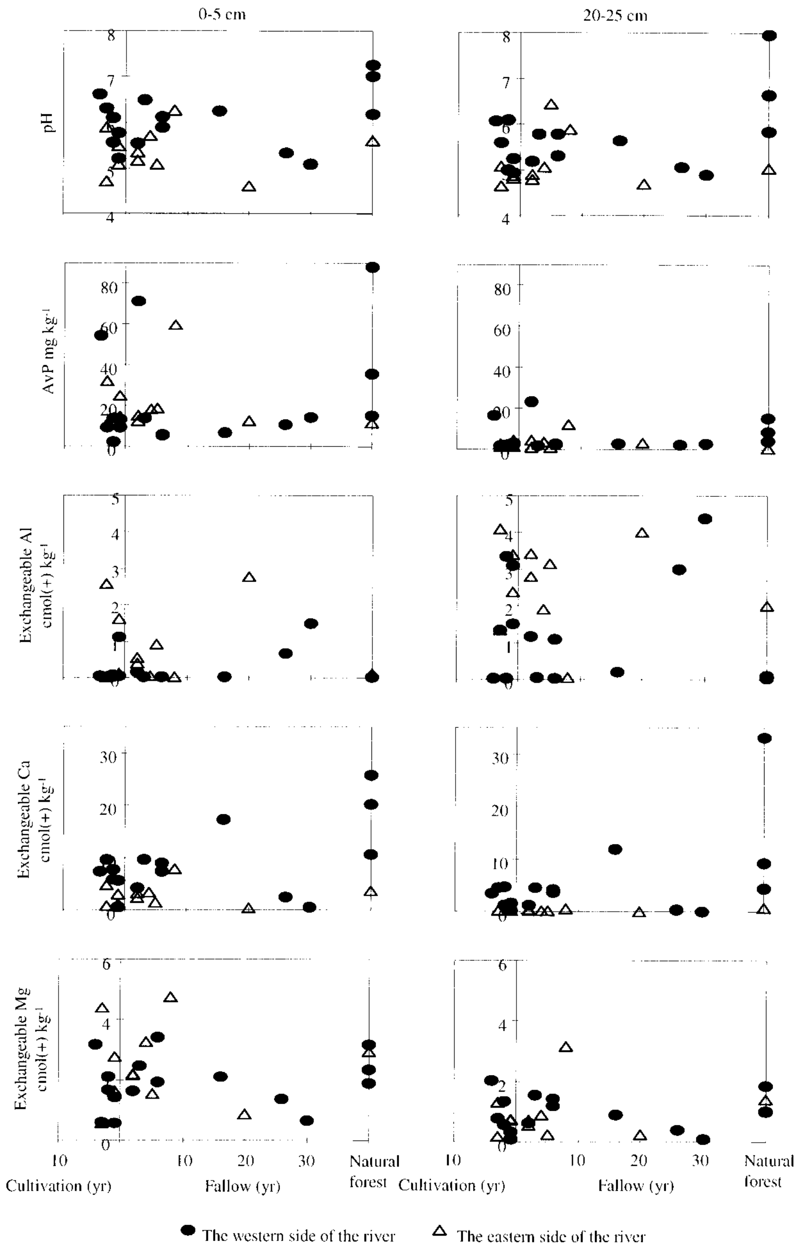


Fig. 2 Relationship between Fallow or Cultivation Period and the Chemical Properties of the Soils at the Depth of 0–5 cm and 20–25 cm in February 2000

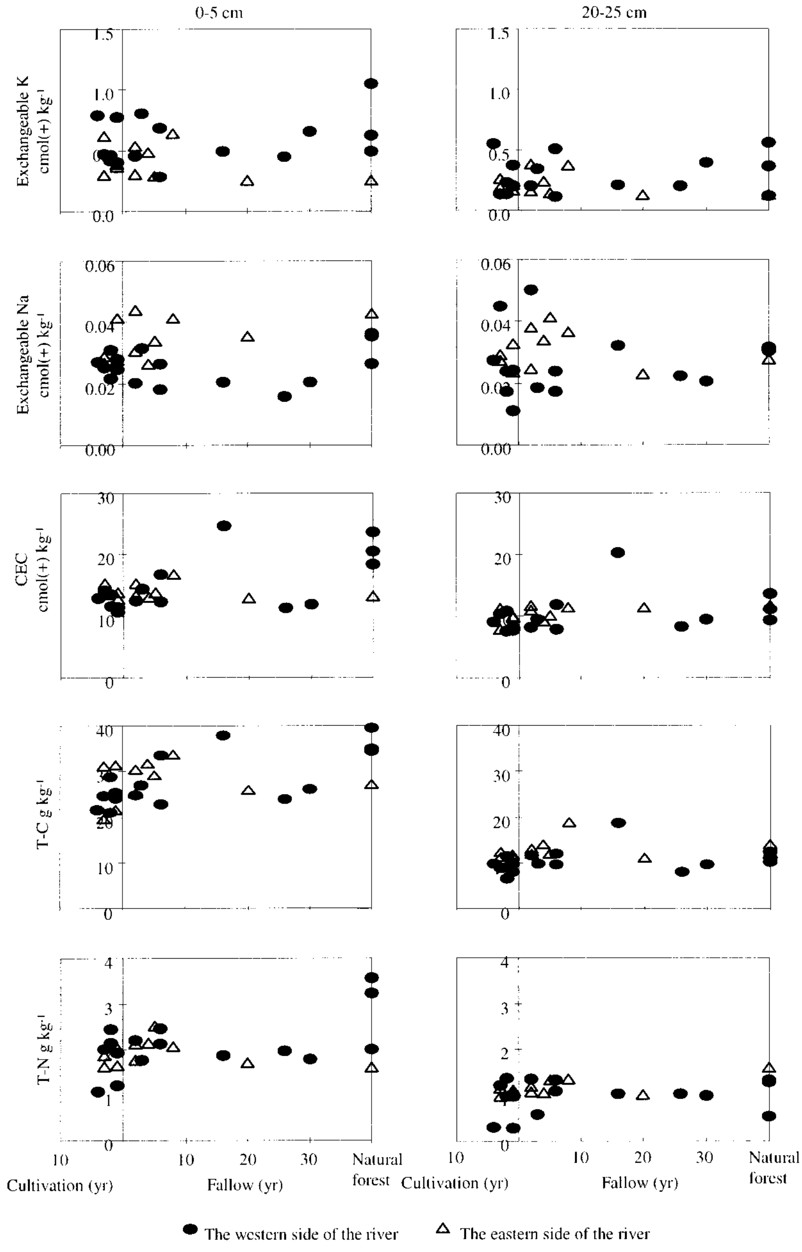


Fig. 2—Continued

al. 1985; Funakawa *et al*. 1997a; 1997b].

The study sites showed low CEC values throughout, irrespective of the high clay content (Table 4). Most of the soils of the study sites can be classified as soils with low activity clay [Uehara 1979]. Av-P content was moderately high under the condition of no fertilizer application by the farmers. On the eastern side, Av-P content showed a slightly higher value than on the western side. There was a significant correlation between the length of fallow period and the amount of T-C in surface soils within the first 10 years fallow (r=0.525, $p<0.05$), while natural forest showed a wide range of T-C value. Fallowing for longer than 10 years does not always contribute to the increase in T-C and T-N contents. T-C and T-N contents of strongly weathered soils may not be easily recovered during fallow period since the original level itself is very low. These values on the eastern side were slightly higher than those on the western side.

Organic matter dynamics under shifting cultivation system have been well analyzed [Funakawa *et al*. 1997a; 1997b; Burbacher *et al*. 1989; Nye and Greenland 1960; 1964], and most authors agree that organic matter and nutrient content in soil increase with longer bush or tree fallow. Roder *et al*. [1995] found, however, that the fallow length showed only a very weak association with soil organic matter. Lack of information on long-term land use history, including land use before present fallow, may cause this discrepancy. Our study suggests that farmers use shorter fallow periods for soils with higher fertility so that it is still difficult to draw definite conclusions about the relationship between soil fertility and fallow length.

IV–4 *Changes of Soil Chemical Properties during the Cropping Period*

Six sites, Fa30, Fa6 and C1 in TKW, and Fa26, Fa6 and C2 in LLW, were cultivated in 2000. The changes in soil chemical properties of these six sites during the cropping period are shown in Table 5.

The pH increased during the period from February to October with the changes in pH greater in the fields with a long fallow than in the fields continuously cropped. This difference can be clearly observed in TKW-C1 and TKW-Fa30. The former showed 0.4 units of difference in pH between February and October, while the latter showed a difference of 0.8 units. This might be due to the larger amount of aboveground biomass available for burning in the field with longer fallow. Kyuma *et al*. [1985] reported that pH increased immediately after burning and decreased immediately after sowing, and pH value after harvest was still higher than immediately after felling the trees. Our findings support this observation.

Exchangeable Al content at the depth of 0–5 cm and 20–25 cm decreased during experimental period except for the 20–25 cm layers at LLW-Fa6 and LLW-Fa26 and the 0–5 cm layer at TKW-C1. Exchangeable H did not show a consistent pattern. Exchangeable Ca and Mg increased except for LLW-C2 and LLW-Fa6. The value of base saturations (BS) in the surface soil increased in all of the study sites. Exchangeable K content was higher in July, and decreased thereafter. The similar change of exchangeable K was already reported

Table 5 Changes in Soil Chemical Properties of the Cultivated Fields during the Cropping Period in 2000

Sample	Depth		pH (H_2O)	pH (KCl)	EC	Exchangeable Cations Al	H	Ca	Mg	Na	K	CEC	BS	AvP	T-C	T-N
	cm				mS m^{-1}	——	——	cmol (+) kg^{-1}	——	——	——	——	%	mg kg^{-1}	g kg^{-1}	
TKW-Fa30	0 – 5	Feb.	5.08	3.88	3.86	1.50	0.62	0.47	0.64	0.02	0.66	11.9	15.1	14.3	26.0	1.8
		Jul.	5.69	4.10	2.81	0.55	0.39	1.97	1.28	0.01	1.00	12.4	34.5	10.2	33.0	1.9
		Oct.	6.05	4.53	2.79	0.16	0.24	2.87	1.79	0.01	0.87	12.5	44.2	25.4	40.4	2.3
	20–25	Feb.	4.89	3.79	1.98	4.39	0.74	0.06	0.08	0.02	0.40	9.5	5.8	2.8	9.5	1.0
		Jul.	4.80	3.82	1.03	3.80	0.52	0.16	0.09	0.02	0.38	7.5	8.6	3.6	8.4	0.8
		Oct.	5.36	4.02	1.66	2.82	0.62	0.39	0.33	0.02	0.58	11.4	11.6	3.7	15.2	1.2
TKW-Fa6	0 – 5	Feb.	6.11	5.33	6.01	0.03	0.00	7.24	1.94	0.03	0.68	12.3	80.2	5.6	22.7	2.1
		Jul.	6.47	5.58	5.45	0.00	0.10	9.01	2.47	0.01	1.25	14.4	88.3	17.2	27.2	2.2
		Oct.	6.92	5.97	5.62	0.00	0.03	10.63	2.54	0.01	0.92	14.7	96.0	25.5	29.4	2.5
	20–25	Feb.	5.78	4.51	1.82	0.03	0.10	4.16	1.20	0.02	0.50	7.9	74.5	2.6	9.5	1.1
		Jul.	6.02	4.72	2.13	0.00	0.13	4.39	1.28	0.02	0.46	9.3	65.9	3.6	10.8	1.1
		Oct.	6.28	4.73	1.43	0.00	0.13	3.97	1.13	0.02	0.61	8.9	64.0	6.6	11.0	1.1
TKW-C1	0 – 5	Feb.	5.20	3.98	3.78	1.12	0.66	0.55	0.55	0.02	0.77	10.8	17.6	13.6	25.4	1.9
		Jul.	5.54	4.01	3.30	1.03	0.51	1.45	0.87	0.01	1.00	11.4	29.3	14.2	27.2	1.8
		Oct.	5.60	4.16	1.73	1.51	0.42	0.91	0.51	0.01	0.72	9.7	22.2	11.9	25.5	1.8
	20–25	Feb.	4.92	3.84	2.04	3.10	0.26	0.09	0.08	0.01	0.37	8.1	6.9	3.2	9.6	1.0
		Jul.	4.86	3.84	1.45	3.48	0.58	0.20	0.13	0.01	0.35	8.0	8.8	4.6	11.9	1.0
		Oct.	5.19	4.03	1.51	3.08	0.60	0.15	0.08	0.01	0.36	8.6	6.9	3.4	14.7	1.2
LLW-Fa26	0 – 5	Feb.	5.32	4.11	3.23	0.67	0.54	2.38	1.35	0.02	0.44	11.4	36.9	10.5	24.0	2.0
		Jul.	5.71	4.26	4.64	0.12	0.35	3.24	1.62	0.01	0.69	11.2	49.7	15.2	25.8	1.9
		Oct.	6.04	4.75	2.63	0.00	0.14	5.33	2.40	0.01	0.26	12.7	62.8	8.9	28.6	2.1
	20–25	Feb.	5.06	3.75	1.50	2.99	0.36	0.38	0.39	0.02	0.20	8.2	12.0	2.3	8.0	1.0
		Jul	4.77	3.78	2.22	3.74	0.54	0.57	0.28	0.02	0.29	8.6	13.3	3.2	9.5	1.0
		Oct.	5.40	4.00	1.12	3.04	0.35	0.98	0.84	0.01	0.14	10.6	18.7	1.8	9.8	1.1
LLW-Fa6	0 – 5	Feb.	5.88	4.97	4.38	0.03	0.03	8.94	3.42	0.02	0.28	16.8	75.2	5.5	33.4	2.5
		Jul.	6.39	5.09	3.52	0.00	0.14	9.12	2.94	0.01	0.56	16.4	76.9	11.4	30.4	2.1
		Oct.	6.30	5.41	2.94	0.00	0.06	10.38	3.10	0.01	0.34	16.4	84.2	5.8	31.6	2.1
	20–25	Feb.	5.30	3.84	1.56	1.09	0.03	3.73	1.44	0.02	0.11	11.9	44.5	2.3	11.9	1.3
		Jul.	5.38	3.78	1.39	3.17	0.72	2.12	0.79	0.02	0.11	10.8	28.3	1.8	10.8	1.3
		Oct.	5.60	4.01	1.23	2.08	0.60	2.61	1.10	0.01	0.09	11.3	33.6	1.2	13.1	1.3
LLW-C2	0 – 5	Feb.	5.55	4.54	4.76	0.08	0.03	5.75	1.65	0.03	0.46	13.5	58.5	2.1	28.8	2.4
		Jul.	5.76	4.35	3.69	0.06	0.32	4.48	1.21	0.02	0.79	12.1	53.6	17.8	24.1	2.0
		Oct.	5.99	4.71	3.16	0.00	0.13	5.22	1.90	0.03	0.59	12.4	62.2	7.7	27.4	2.3
	20–25	Feb.	5.00	3.73	1.56	3.33	0.42	1.23	0.55	0.02	0.14	10.8	18.1	2.3	11.5	1.4
		Jul.	4.73	3.73	2.35	4.71	0.59	0.47	0.24	0.02	0.19	9.0	10.2	2.5	10.0	1.3
		Oct.	5.03	3.89	1.86	2.78	0.59	0.83	0.48	0.02	0.15	9.2	16.0	2.1	13.6	1.4

[Tulaphitak *et al*. 1985; Stromgaard 1984]. AvP showed an increase at the fallow fields of TKW and a peak in July at Fa6 and C2 of LLW. The amount of T-C of the surface soil slightly decreased at LLW-C2 and Fa6, and increased at the other sites. There was little change in T-N content, although it increased at the surface soil of TKW-Fa6 and Fa30. It is reported that soil temperature increased and N mineralization decreased with increase in the amount of burned biomass [Tanaka *et al*. 2001]. We found an increase in T-N which suggests that, at least, the sustainable amount of biomass was burned for N mineralization. The biomass of the fallow vegetation generally represents the major pool for calcium, magnesium and potassium [Andresse and Schelhaas 1987; Nye and Greenland 1960; 1964; Sanchez 1987]. The changes in nutrients are, therefore, affected by the amount of vegetation biomass. The nutrients mostly increased after burning and cropping in this study, although the changes of different kinds of nutrient during the cropping period varied from site to site.

These results suggest that the accumulation of nutrients from ash was higher than the loss of nutrients during cropping. However, the increase in soil nutrients in the three years continuously cropped field (LLW-C2) was smaller than that in single year cropped fields. This indicates that continuous cropping without fertilizer degrades soil fertility and exhausts soil nutrients finally.

V Significance of the Fallow Period

Nakano [1978] noted that the soil fertility had only just recovered after 5 years fallow for shifting cultivation fields in northern Thailand and Zinke *et al*. [1978] found that the recovery of nutrients in the soil after only 1 year of cropping had barely been achieved after 9–10 years of fallowing. Despite these fertility constrains, Tulaphitak *et al*. [1985] suggested that decline in soil fertility might not be the decisive factor motivating farmers to fallow their fields even after 2 years continuous cropping. In our study, most of the nutrients were more abundant after harvest than before planting, and the supply of nutrients from ash was higher than the loss for cropping. These results suggest that soil fertility recovery was not the only, or even the most important reason why farmers fallow fields.

Local farmers consider that the fallow period is short if it is less than 6 years. They believe that short-fallow fields have more weeds. They have to weed four times per crop in case of short-fallow, whereas only two weedings are needed in the case of long-fallow. Roder *et al*. [1994] reported that the weeding requirement increased from 1.9 to 3.9 times with the decrease in the fallow period from 38 to 5 years. Weed control is significant for sustaining rice yields. Kamada *et al*. [1987] reported that burning suppressed the germination of seeds of annual herbs or grasses and stimulated seed germination of woody species.

The biggest difference between short- and long-fallow can be found in vegetation recovery. The typical vegetation after short-fallow is herbaceous whereas woody species predominate in long-fallow, and there must be more weed seeds in short-fallow fields than in long-fallow fields. The intensity of the fire after short-fallow must be less than after long-fallow because of differences in the composition and volume of biomass. This results in more weeds for short-fallow. Therefore, we conclude that the significance of fallow period is to get a large amount of biomass to control the weeds by burning.

VI　A Sustainable Farming System for Short Fallow Fields

Population growth and enforcement of government regulations against clearing new fields in forest areas will inevitably force intensification of cropping on existing agricultural fields with a consequent reduction in the length of the fallow period. Are there any potential farming systems that can sustain production under such conditions? Based on the discussion in the previous sections, it can be concluded as follows: soils in the study area have reasonably high content of soil nutrients despite being on erosion-prone sloping land. Soil fertility status may not be fully restored even when the length of fallow is 10 years but the accumulated nutrients in the soil during fallow period are small compared with the nutrients supplied from the ash input when the biomass is burned so that soil nutrients were found not to be exhausted after a single year of cultivation. However, the density of weeds increases if the fallow period becomes shorter. Therefore, fallow plays an important role in weed control during the cropping period, whereas its function for recovering soil fertility is weak. Given this situation, what type of farming system might be sustainable?

As one promising system, we propose the introduction of paper mulberry (*Broussonetia papyrifera*) during fallow in the system. Paper mulberry is a shrubby tree that commonly appears as a pioneer species in swidden fields in Northern Laos. If left undisturbed the trees regenerate during the fallow period. Villagers have long harvested the inner bark of stems of mulberry trees grown in bush fallows for local processing into a coarse-textured parchment. Recent development of a domestic processing industry and the opening of export market channels have encouraged farmers to retain paper mulberry volunteers in their swidden fields and to begin experimenting with propagation and intercropping systems to intensify production of the cash crop in fallow fields [Fahrney *et al*. 1997]. Luang Phabang and Xayaburi are currently the center of paper mulberry production in Laos [Tajima 2000].

Okabayashi [2002] reported that the values of pH, exchangeable Ca and K, and AvP in soils increased with the length of the paper mulberry planting period. Although it is not yet clear whether the soil fertility improvement is directly related to the planting of paper mulberry or not, we think that growing paper mulberry trees does not cause significant nutrient loss. According to Kang [1997], the presence of woody species in the alley cropping production system contributed to (1) nutrient recycling, (2) reduction in soil nutrient leaching losses, (3) stimulation of higher soil faunal activities, (4) soil erosion control, (5) soil fertility improvement, and (6) sustained levels of crop production. We can expect the same effects by introducing paper mulberry planting to swidden agriculture. Moreover, we can expect it to generate a large amount of aboveground biomass even after short-fallow. According to our measurement in the study site, paper mulberry can yield 10 tons of biomass per hectare per year, while herbaceous vegetation yields 6 tons. Burning this large amount of biomass will increase fire intensity and suppress germination of weed seeds. Farmers can also obtain some income from selling the inner bark of paper mulberry. This economic incentive should help to spread of this agroforestry system easily. It is, therefore, necessary to widely study the applicability of this system both from agronomic and economic viewpoints.

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Intensification of Shifting Cultivation by the Use of Viny Legumes in Northern Thailand

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Abstract

The present study describes a complex multiple cropping system of six crops which has evolved in a Lisu village in Chiang Mai during the last 17 years. The system involves relay planting of three viny legumes [cowpea (*Vigna unguiculata*), rice bean (*Vigna umbellata*) and lablab bean (*Lablab purpureus*)] after inter-cropping of maize and wax gourd (*Benincasa hispida*) or pumpkin (*Cucurbita moschata*). The relay-cropping of the three viny legumes could be considered as a locally evolved type of accelerated seasonal fallow management aimed at soil fertility replenishment and income generation in an intensified shifting cultivation system. The Lisu farmers adopted this system because of their prior experiences on market economy and their knowledge of multiple cropping technology through previous maize-opium based farming, as well as because of the availability of a large area of fertile land to sustain intensive cultivation without external inputs. The ability of the multiple cropping system to generate acceptable income and the availability of transportation for the products were also positive factors favoring its adoption. On the other hand, its lower profitability than competitive cropping systems, such as vegetable seed production, and its requirement for good transportation, large farm size and fertile soils constrained its expansion. The present study also revealed that external factors of economy and technology development are crucial in determining if environmentally beneficial cropping systems will continue in use in the long-term or be replaced with less environmentally friendly agricultural practices.

Keywords: viny legumes, rice bean, lablab bean, cowpea, accelerated fallow, relay cropping, shifting cultivation, Northern Thailand

I Introduction

Increase in population and, consequently, growing pressure on land have resulted in a shortening of the fallow period of shifting cultivation in Northern Thailand. This may cause decline in agricultural productivity and increased vulnerability to environment hazards. One measure to cope with a shorter fallow period is to improve fallow management. Shifting cul-

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tivators also face changing circumstances such as improvement of transportation and communication, and spread of the market economy. Increased extension services by the government sector and NGOs help by introducing new crops, cropping patterns and agricultural inputs even to remote areas. These new circumstances and technologies, in addition to indigenous knowledge, may help to mediate the pressure on land and also to upgrade the livelihood of shifting cultivators.

A complex multiple cropping system of relay growing of three viny legumes [cowpea, (*Vigna unguiculata*), rice bean (*Vigna umbellata*) and lablab bean (*Lablab purpureus*)] after inter-cropping of maize and wax gourd (*Benincasa hispida*) or pumpkin (*Cucurbita moschata*) has evolved over the past two decades ago in a Lisu village in Northern Thailand. The system can be considered as a type of intensified shifting cultivation by means of introducing commercial crops and improving fallow management. The present study describes the process of innovation, examines the functions and limitations of this intensified shifting cultivation, and discusses the applicability of intensified shifting cultivation to other areas in the mountainous regions of Mainland Southeast Asia.

II Study Area and Field Survey

Huai Nam Rin, Huai Go and Mae Pam Norg villages in Chiang Dao district, Chiang Mai, were selected as the sites for the present study. Mae Pam Norg and Huai Go villages are 11 km apart, and were established some 50 and 40 years ago by Northern Thai and Karen people, respectively. Later, Akha, Hmong and Lisu migrated into these villages. Huai Nam Rin village was established in 1978 in a relatively undisturbed forest between the two villages by Lisu people because the two old villages were then already too crowded. The main characteristics of the three villages are summarized in Table 1.

The climate is tropical monsoon with mean annual rainfall of 1,250 mm and a pronounced dry season during the period from November to April. The elevation of the area is about 500 m above mean sea level. The natural vegetation was mixed deciduous forests. These villages are located on a long narrow foothill between a limestone mountain on one side and a shale/schist mountain on the other side. The cultivated lands have soils derived from limestone and are relatively flat compared to other shifting cultivation areas in Northern Thailand [Kunstadter and Chapman 1978]. All fields are located inside legally declared national forest reserve land.

At present, maize is the major crop in the three villages. The old villages also have lowland paddy fields. Cultivation of upland rice has already disappeared in the three villages, though it is still continued, particularly as a ritual crop, in nearby villages.

The first field survey was done in April 1997. We conducted participatory rural appraisal (PRA) exercises two times in Huai Nam Rin village and group interviews with farmers in Huai Go and Mae Pam Norg villages. We re-visited the villages in February 2002 and con-

Table 1 Some Important Parameters of the Three Villages

	Huai Nam Rin	Huai Go	Mae Pam Norg
Ethnic Groups	Lisu	Karen, Akha, Lisu	Thai, Hmong, Lahu
No. of households	70	98	62
Years of establishment	1978	Some 50 years ago	Some 40 years ago
Road assessment	Unpaved roads Difficult to access in the rainy season	Unpaved roads Difficult to access in the rainy season	Paved roads All year round accessible
Legal landuse rights	None	None	Some
Distance from Huai Nam Rin	—	7 km	4 km
Main soil types	Clayey Oxic Paleustuls with very good soil structure		
Slopes of cultivated areas	5–20%	5–20%	5–20%
Elevations	460–500 m	560–600 m	460–500 m
Average land holding per household	4 ha	3 ha	2 ha
Off-farm employment	None	Yes	Yes
Lowland rice fields	None	Yes	Yes
Upland rice cultivation	None	Yes	None
Farmers who practiced the system	Almost all	More than half	About a quarter

ducted group interviews with farmers. We also collected soil samples and analyzed their physical and chemical properties to evaluate changes in soil fertility.

III Shifting Cultivation Systems before the Innovation

Conventional shifting cultivation systems in Northern Thailand vary among ethnic groups. In general, they are upland rice and maize-based mixed cropping under the rainfed condition. Other vegetable crops such as cucumber (*Cucumis sativus*), wax gourd (*Benincasa hispida*), pumpkin (*Cucurbita moschata*), angled luffa (*Luffa acutangula*), sponge gourd (*Luffa cylidrica*), chili pepper, etc. were inter-cropped in upland rice and maize fields. The Karen and Lua adopted a "short cultivation–long fallow system" because they were permanently settled in valleys and have been also engaged in lowland paddy cultivation and orchard growing. Being relative newcomers to Northern Thailand, Hmong, Lisu and Akha had to settle on relatively higher and steeper terrain. They traditionally had no lowland paddy and orchards, and depended fully on shifting cultivation. The major cash crop was opium. They grew opium by relay-cropping with maize, planting opium one month before maize harvest [Keen 1978]. The whole community moved to a new settlement when the surrounding cultivated lands were exhausted. Their system was described as "long cultivation–very long fallow system" or "pioneer shifting agriculture" [Kunstadter and Chapman 1978].

In the study area, maize replaced upland rice as the core crop of shifting cultivation several decades ago. Farmers sell maize and buy rice for their home consumption. About the half of the farmers in Huai Go village still grew upland rice in the late 1990s as a ritual crop, but no farmers in Huai Nam Rin and Mae Pam Norg villages grow upland rice any more. This indicates that farmers of the study area have adopted a market-oriented strategy of farm management even before the innovation of shifting cultivation system.

The Hmong, Akha and Lisu who migrated into the study area could not grow opium in their new lands because the climate was too warm due to the low elevation. Instead, they grew many kinds of fruit trees, mango in particular, as cash crops. Farmers reported that strict reforestation programs accerelated the creation of mango plantations, even in shifting cultivation fields far away from the settlements, because planting fruit trees was a way for them to make their land claims more secure, as Pahlman [1992] reported.

Farmers identified marketing of the products, weeds, reforestation program, soil quality declining, insects and diseases, and drought as the major farming problems. Soil erosion was not recognized as a severe problem for them.

IV Innovative Shifting Cultivation

IV–1 *Introduction of Viny Legumes*

When the farmers settled down in the present locations, they did not know rice bean and cowpea. They knew lablab bean but did not widely grow it. The innovation of relay-cropping of maize and viny legumes has been evolved at Huai Nam Rin village by means of upscaling of indigenous technology and application of external knowledge since 1980, two years after the establishment of the settlement.

Relay-cropping of lablab bean with maize started in 1980. A woman farmer found some seeds of lablab bean in a sack of unhusked rice which she bought from another village. As she opened the sack in maize field, she planted the seeds there. Relay-cropping was an old practice for them because they were accustomed to grow opium with maize before. So the practice of growing lablab bean in maize field was quite natural for them.

In 1982, two years later, a Lisu farmer who had migrated from Kampaeng Phet started to grow rice bean. He obtained the seeds of rice bean as well as planting recommendations from an officer of Department of Land Development at Kampaeng Phet.

Cowpea[1)] was first introduced to the study area by one of the authors. This was the native climbing type, but was not accepted by farmers due to low yields. Then, the bush type of cowpea was introduced in 1993. The seeds of cowpea were accidentally left on a truck of a middleman, and farmers freely got them. This type of cowpea was already grown as a second crop in Prao district, approximately 20 km away.

IV–2 *Cropping Calendar and Technology*

A complex cropping system using viny legumes was established after many trials and errors in Huai Nam Rin and two neighboring villages. The cropping calendar of this system is sum-

1) Both rice bean and cowpea (bush type) were originally developed at the International Institute of Tropical Agriculture (IITA) (personal communication with Prof. A. Thirathon, Department of Agronomy, Mae Jo University).

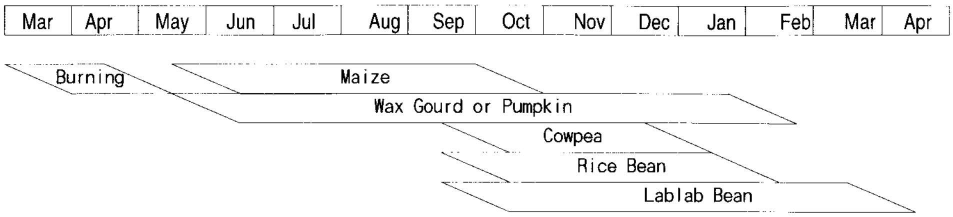

Fig. 1 Cropping Calendar of the Complex Innovated Multiple Cropping System

marized in Fig. 1. The main element of the system is the inter-cropping of maize with wax gourd or pumpkin, with the relay-cropping of the three viny legumes as a subsidiary element. This intensive cropping system is used in fields where there are no trees or small fruit trees, and it is not applicable in fields with mature fruit trees.

In March and April, fields are first weeded with hoes and the crop and weed residues piled and burned. Farmers reported that the functions of burning are to suppress weed growth and to mitigate pests and diseases. Delay in the harvest of previous lablab bean crop causes delay in the field preparation, which reduces the effects of burning. Use of farm tractors is prohibited in the study area by the Forestry Department as a way to keep farmers from expanding the cultivated land, although deforestation is still going on and the cultivated land is actually expanding.

In May, maize and wax gourd or pumpkin are sown together. They are inter-cropped by simply mixing the seeds of both crops at the ratio of 20 to 40 : 1 for maize and wax gourd or pumpkin seeds. Land is not plowed before sowing and the seeds are put in holes which are manually dug by spade. Plant spacing of maize is approximately 70 × 50 cm with two plants per hill, while the best spacing of wax gourd is 2 × 2 m. Wax gourd is thinned if the plants grow too closely. The major variety of maize is Suwan 5, an open-pollinating variety.

Chemical fertilizer is seldom used. Weeding was formally totally done by hand, but use of herbicides has recently been spreading due to lack of labor. Labor shortage also provides farmers with the incentive to introduce farm machinery into their cultivation, and actually some farmers have started to use power tillers.

Cowpea, rice bean and lablab bean are separately sown in maize fields one month before the harvest of maize. Before sowing the legumes, weeding is done once and the vines of wax gourd or pumpkin are pulled out and piled in circular areas of 1–1.5 m far from their hills in order to open space for the legumes to grow. Farmers said that this practice did not harm the growth of wax gourd but stimulated the sprouting of new shoots, which resulted in higher yields. The legumes are planted in between the rows of maize. The plant spacing is 70 × 50 cm for rice bean and lablab bean and 70 × 30 cm for cowpea. The labor availability of each farmer determines what proportion of the maize field is relay-cropped, but in most cases relay-cropping is practiced not in the whole area. Sowing of the legumes could be extended until the end of October if there is enough rain in the second half of the month.

The harvest of the six crops is distributed from October to April. In October, maize is harvested, followed by cowpea in December and January, wax gourd, pumpkin and rice bean in January and February, and lablab bean in March and April. Wax gourd and pumpkin fruits which lay on the ground are easily picked after the harvest of cowpea and rice bean. On the other hand, harvesting of wax gourd in lablab bean fields is difficult since the fruits are covered with bean canopies and fully grown green pods of lablab bean contains certain oil with unpleasant smell that caused skin irritation.

Lablab bean is not grown in fields with mango trees because the plants fully cover the ground during the whole dry season. This vegetation provides habitats for rats that may destroy the trees. The high risk for fire that could destroy the young trees is another reason.

IV–3 *Impact on Soil Properties*

In order to examine the impact of the above-mentioned relay cropping on soil properties selected indicators of soil property such as pH, organic matter content and available phosphate, in addition to yields of maize, were measured in four pairs of cultivated fields with and without relay cropping and with each pair having been under continuous cultivation for different lengths of time, and three plots of disturbed forests (with burned undergrowth plants) near the cultivated fields. The available phosphate was measured by the Bray II method. The yields of maize were calculated by dividing the production obtained from the farmers by the field area measures by the global positioning system (GPS) device. The results are shown in Table 2.

Soil organic matter shows a clear decreasing trend corresponding to the length of cultivation period for both cases with and without relay cropping. Available phosphate also decreases according to the length of continuous cropping, but this trend was not clear in case without relay cropping. pH shows neither increasing nor decreasing trends in both cases. Compared to non relay-cropped fields, relay-cropped fields always show higher organic matter content. Available phosphate of relay-cropped fields is higher until five years of continuous cropping and smaller afterward than that of non relay-cropped. These results suggest that relay cropping of viny legumes facilitated the delay in the depletion of soil organic matter and available phosphate, but its effect on available phosphate disappear in

Table 2 Changes in Soil Property by Cropping Pattern and Length of Continuous Cropping

Length of Continuous Cropping	pH		Organic Matter		Available Phosphate		Maize Yields	
	Relay	Non Relay	Relay	Non Relay	Relay	Non Relay	Relay	Non Relay
No cultivation (forest)	6.3		6.10		94		—	
3 to 4 years	6.3	6.2	5.61	4.42	119	97	3.26	1.57
5 years	6.1	6.7	5.29	5.43	96	70	4.71	3.55
10 to 11 years	6.2	6.4	4.42	3.23	70	83	3.00	2.12
15 to 17 years	6.6	6.8	3.93	2.92	57	87	3.55	2.62
Average	6.3	6.5	4.81	4.00	86	84	3.63	2.47

case of long continuous cultivation.

The overall average yield of maize is 3.05 t/ha. This is almost 50% higher than the national average, reflecting the presence of limestone-originated fertile soil in the study area. The average yield of maize with legume relay-cropping was 3.63 t/ha, which is obviously better than that without relay-cropping, 2.47 t/ha. Higher mineralization of nutrients, especially nitrogen, due to higher organic matter contents is thought to be the dominant reason for the better performance of maize in the relay-cropping system. Farmers pointed out the relationship between maize yields and the family labor supply. The households who adopt the relay cropping system usually have sufficient family labor, so that they also input enough labor for weeding. This causes higher yields of maize.

IV–4 *Farm Economy*

The income obtained from the innovative cropping system in Huai Nam Rin village was roughly estimated based on information obtained through field survey. The total production of the six crops in the year 1996/97 was estimated by counting the number of different sizes of trucks that transported the products. The unit price of the products varied by season, though, so we used the average prices. It must be noted that middlemen usually offered a better price to them than to their neighboring villages because Huai Nam Rin village produced much bigger volume of products. This is one of the advantages for this village to promote this cropping system. The results of the estimation are summarized in Table 3.

The biggest income comes from the sale of maize, which account for about half of the gross income. The three viny legumes provide in total about 40%. This clearly indicates the economic importance of these crops. The average gross income in the village was US $2,700/household. Some farmers have additional income from the sale of fruits. Most of the farmers were satisfied with this income status which was comparable to the income which they had earned from opium.

IV–5 *Improvement of the Productivity of the System*

Farmers of Huai Nam Rin village recognized the significant impact of modern technology such as hybrid varieties of maize, tillage using farm tractors and chemical fertilizers on the

Table 3 Production and Cash Incomes of the Innovative Cropping System in Huai Nam Rin Village (1996/97)

Crops	Production (t)	Unit Price (US$/t)	Gross Income (US$)
Village total			
Maize	700	135	94,500
Cowpea	80	425	34,000
Rice bean	100	290	29,000
Lablab bean	80	230	18,400
Wax gourd	220	58	12,760
Pumpkin	15	192	2,880
Average per household			2,736

productivity of the system when we surveyed in 1997.

In 1996 some farmers started using a hybrid variety instead of an open-pollinating type of high-yielding variety, Suwan 5, which was widely used before, and experienced 50% higher yields. Then in 1997, almost all households in the village adopted the hybrid maize variety, even though the cost of seeds was rather expensive, US$5 per kg.

We also proposed earlier relay-cropping of legumes as a measure to improve the productivity of the system. A research study done in Chiang Mai showed that relay growing of cowpea and lablab bean with maize did not affect maize yields if cowpea and lablab bean are sown 60 to 100 days after the sowing of maize [Insomphun and Kanachareonpong 1991]. This research also showed that legume yields increased with earlier planting. Yields of cowpea and lablab bean sown 60 days after maize planting were 14 and 10 folds higher than those sown 100 days after maize planting, respectively. Some farmers seemed to be interested in this proposal and actually tried earlier planting of legumes in small patches of their fields, but the results are not known.

IV–6 *Collapse of the System*

In 2000 and 2001, the prices of the three viny legumes dramatically dropped. The prices of rice bean and cowpea have decreased to about half that of the earlier years, while the price of lablab bean has reduced to less than a quarter. These changes in prices pushed farmers to replace the viny crops with groundnut, which had a good price at that time. In the 2002 cropping season, rice bean and cowpea have completely lost their places in the system, although some farmers continue to grow lablab bean in 2002 as a fallow crop in summer.

Changes in crops from viny legumes to groundnut caused serious problems in the form of thick weed growth and hard soil. These must be partly due to long and continuous cultivation with no tillage.

Hard soil is a problem at the time of harvesting groundnut, which must be pulled out from the ground. The Forest Department, therefore, relaxed enforcement of the regulation against using tractors. Some farmers actually started using them for plowing fields before cropping, but this practice has only spread to a limited extent.

Use of herbicide is spreading. The number of herbicide users has increased and types of herbicides changed. Herbicide previously used in maize fields was Gramoxone, a contact non-selective herbicide which destroys only parts of wax gourd and pumpkin plants that directly contact with the herbicide. Herbicide presently used is Atrazine, a selective systemic herbicide killing all broad leaf weeds. Although inter-cropping of wax gourd and pumpkin decreased, their cultivation still continue because markets are available for these crops.

When we talked with farmers in 1997, some farmers mentioned that most of their fields would be full with fruit trees, mango in particular, within 10 years. This idea expressed their perspective that they can earn more income with less labor input from orchards than from the relay cropping system. Actually some maize fields with relay cropping of viny legumes have been replaced by mango plantations since then, but the expansion of orchard was not as much as it was expected in 1997. The sharp drop of mango price in the past several years could be a primary reason.

V Discussion

V–1 *Factors that Contributed to the Innovation*

Several factors can be raised as possible driving forces to establish the innovative system.

1) The Needs for New Cash Crops

Since 1985, cultivation of opium has been strictly controlled by the government by means of cutting all opium crops found in fields [Seetisarn 1995]. This measure forced opium growers to seek for new cash crops, and some people moved and established new settlements in order to grow different kinds of cash crops which can substitute for opium. Migration of the Lisu families, former opium growers, to Huai Nam Rin village during the period between 1986 and 1990 is a part of this movement. They had to establish a new cropping system including cash crops without opium in the new land.

2) Farmers' Experience with Multiple Cropping

Farmers had previous experience of a complex cropping system, inter-cropping of maize and vegetables and relay-cropping of opium. This was a part of the traditional farming system of opium growers [Keen 1978]. Idea from and techniques of the traditional farming must have helped in establishing the innovative system.

3) Availability of Land to Generate Acceptable Income from the Innovation

The average farm size of Huai Nam Rin village is 4 ha, while it is 3 ha in Huai Go and 2 ha in Mae Pam Norg villages (Table 1). Thus, farmers in Huai Nam Rin village possessed comparatively big farms with sufficient land to generate an acceptable income from the system. The farmers adopting the system in Huai Go and Mae Pam Norg villages also hold bigger farm lands than the non-adopters. Small land holders in Mae Pam Norg village were engaged in contract farming to produce seeds of flowers and vegetables because it is labor-intensive and they could earn higher income per unit area. In addition, the village is located along a paved road and most of the farmlands there were accessible by pickup trucks even in the rainy season, which is a prerequisite condition of contract farming for seed production. The non-adopters who have smaller lands than contract farmers had to earn money from off-farm jobs.

4) The Need for an Efficient Weed Control System

The prohibition of the use of farm tractors in the villages has compelled the farmers to adopt other efficient weed control systems instead of annual plowing. The fast growing vegetables such as wax gourd and pumpkin have provided farmers with better weed control during their early growing stage. These crops also were additional income sources because farmers sell them to a local military camp. The dual functions of growing wax gourd and pumpkin accelerated the expansion of their cultivation. At present, wax gourd is collected by local middlemen and sent to food factories in Bangkok. Farmers also recognize the effectiveness of relay-cropping of the three viny legumes on weed control.

5) High Ability of Limestone-based Soils to Sustain Cultivation

Before the Lisu families migrated, they carefully selected lands for resettlement. They selected the present Huai Nam Rin village because the area was covered with dense mixed deciduous forest with limestone-originated soils, and they judged, based on their experiences, the land could sustain intensive and continuous cultivation for several years. Such knowledge of shifting cultivators in Thailand is also reported by Keen [1978] and Kunstadter and Chapman [1978]. These soils have high pH and calcium content, which are essential for efficient nitrogen fixation of Rhizobium and growing of most legumes.

6) Availability of Transportation for the Products

Huai Nam Rin village was just four kilometers away from a paved road. The village was easily accessible by an earth road during the dry season.

V–2 *Constraints on Expanding the Innovative System*

The innovative system spread in the study area, but did not cover the whole study area. Almost all 70 households in Huai Nam Rin village have practiced the system but the share of adopters of the system in the two neighboring villages varied from a quarter to a half of the village households. This type of cropping system is seldom observed in nearby areas. The constraints for expanding the system are thought to be as follows.

1) Market for the Products

Although relay-cropping of legumes provides better weed control and soil fertility improvement, farmers said that they would only practice this system in small areas just enough for household consumption if they could not sell their products. The quick change of crops from viny legumes to groundnut when the prices of legumes sharply dropped reflected this idea. These clearly indicate that the farmers' decision for cropping system is primarily based on the profitability of the system. This is the biggest constraint for the expansion of relay-cropping of legumes.

2) Transportation of the Products

This innovative system needs good transportation at least in the dry season. In the case of Huai Nam Rin village in 1996/97 cropping year, big trucks were needed to transport the 1,195 tons of products from the village center (Table 3), and pickup trucks for collecting the products from the fields to the village center. This suggests that this system could not be adopted in remote villages inaccessible by trucks and pickup trucks.

3) Big Farm Lands

One major reason why there were non-adopters of relay-cropping in Mae Pam Norg village was the insufficient farm size. Land holding was not big enough to adopt the innovative system to generate an acceptable level of cash income. A non-adopter in Mae Pam Norg village figured out that the maximum gross income earned from the system was US$700 per ha. Thus a household should have three to four hectares of farm land to earn an acceptable income. Being contract farmers for vegetable and flower seed production could enable them to earn about US$1,900 per ha. Farmers possessing only one to two hectares of farm, therefore, prefer contract farming to the innovative system, if they have a good road access.

4) Soil Fertility

The innovative system is a form of semi-permanent intensive cultivation. The use of chemical fertilizer is still not popular so that production depends completely on the mining of soil nutrients. The results of soil analyses indicate that soils of Huai Nam Rin village originally contained very high levels of phosphorous and could, therefore, maintain the high nutrient availability even after 17 years of cultivation (Table 2). This suggests that upgrading of soil properties is a prerequisite for applying the innovative system to poor soil areas.

VI Conclusions

The process of creation and collapse of a complex multiple cropping system at a Lisu village in Northern Thailand was studied. The following factors were considered as mechanisms that contributed to the system's innovation by the farmers: their prior experiences with the market economy and multiple cropping technology through previous maize-opium based farming; availability of big farms with fertile land to sustain intensive cultivation without external input and to generate acceptable income; availability of transportation for the products. The prohibition of using of farm tractors in national forest reserve, which forced the farmers to attempt other efficient weed control systems, could be considered as another mechanism.

Although relay-cropping of viny legumes is, agronomically speaking, an excellent cropping system that helps to control weeds and improve soil fertility, this system does not cover the whole study area. Constraints on the expansion of the system are: lower profitability than competitive cropping system such as seed production; bad transportation conditions; small farm size and less fertile soils.

Sustainability of the cropping system is primarily controlled by economic, ecological and technical factors. This case study, however, clearly showed the importance of the economic factor. The determinant factor of crop selection, a major component of the system, was the changes in crop prices. When prices of the three legumes dropped, farmers quickly replaced them with other crops, such as groundnut, which were more profitable. Nevertheless groundnut is less advantageous than viny legumes from the ecological viewpoint in terms of providing soil cover.

Another factor influencing the long-term dynamics of the system is the main stream agricultural technology such as the use of farm tractor and herbicides. These technologies respond to the need of farmers to manage land and labor more efficiently. What is going on in the mountainous region in Northern Thailand is, unfortunately, that these technologies lead to adoption of agricultural practices that are less environmentally friendly than the original ones. It is urgently required to utilize main stream agricultural technology in ways that lead to better management of mountain agriculture.

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Some Key Issues Relating to Sustainable Agro-resources Management in the Mountainous Region of Mainland Southeast Asia

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Abstract

Most of the people who live in the mountainous region depend on agriculture for their livelihood. They are facing increasing difficulties in meeting their daily subsistence needs, let alone raising their living standards to levels enjoyed by the lowland populations. At the same time, the agro-resources on which the economic welfare of the mountain people depends have been suffering severe degradation with consequent reductions in productivity. Finding ways to intensify agricultural production in a sustainable manner is a critical problem facing both the farmers who inhabit the mountainous region and for the national governments of Laos, Thailand, and Vietnam. In this paper, drawing on the detailed case studies of specific local areas that are presented in the papers in this special issue, we describe some key problems facing agricultural populations in the mountains, examine the driving forces for change, look at the adaptive responses of the farmers to the changing resource situation in the mountains, assess some potential solutions, and set-out some research priorities.

Keywords: population pressure, resource degradation, upland agriculture, Laos, Thailand, Vietnam, human adaptation

I Introduction

The mountainous region of Mainland Southeast Asia stretches from Assam and the Northeast Frontier territory of India across Myanmar, Laos, Thailand, and Vietnam into Yunnan in China. This vast region is physically very diverse. It includes high, sometimes snow-covered mountains, large intermontane basins (e.g., Dien Bien in northern Vietnam), broad plateaus (e.g., the Khorat Plateau in Northeast Thailand), and rolling hills. Thus, although we refer to it in this paper as the mountainous region, not all of its inhabitants live on the steep slopes that this word normally calls to mind. The diversity of land forms in the region is matched by climatic and edaphic diversity and a concomitant diversity of natural vegetation types and cultivated crops. Linguistic and cultural diversity are also extremely high making it difficult to identify any commonly shared characteristics of the region as a

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whole. One common feature, however, is that most of the people who live in the mountainous region depend on agriculture for their livelihood. These people are all facing increasing difficulties in meeting their daily subsistence needs, let alone raising their living standards to levels enjoyed by the lowland populations. Even in countries such as Vietnam where the income of the mountain people has increased considerably in recent years, there is a growing gap between the economies of the mountains and the lowlands that leaves the mountain people relatively worse off than before. Meanwhile, the agro-resources on which the economic welfare of the mountain people depends have been suffering severe degradation with consequent reductions in productivity. Finding ways to more sustainably manage agro-resources is therefore the major challenge for mountain area development. In this paper, drawing on findings of the other papers in this special issue, we will describe some key problems facing agricultural populations in the mountains, examine the driving forces for change, look at the adaptive responses of the farmers to the changing resource situation in the mountains, assess some potential solutions, and set-out some research priorities.

II Key Problems of Agricultural Development in the Mountainous Region

The current situation of the farmers in the mountainous region is a very difficult one. They face severe problems of inadequate food security, poverty, economic and social marginality, and environmental and resource constraints of agricultural productivity. We will discuss each of these problems in turn.

II–1 *Food Security*

Producing sufficient grain to meet basic nutritional needs is the most critical problem faced by most farmers in the mountains. Yamada *et al*. [2004] point out that while at the national level the average per capita rice supply in Laos is 320 kg, in the mountainous areas of northern Laos annual production fluctuates between 227 and 313 kg, making this region the most prone to rice shortages in the nation. In the communities in northern Laos studied by Watanabe *et al*. [2004] 70 percent of the shifting cultivator households were unable to produce enough rice to meet their consumption needs in 2000, up from 40 percent in 1999. The situation in the villages studied by Yamada *et al*. [2004] in northwestern Laos is similar. In the lowland villages relying on paddy rice, 20 percent of households are food short for more than four months per year, 40 percent faces shortages for from one to three months, and only 20 percent are able to meet their annual food needs. Surprisingly, in the mountain villages that rely wholly on shifting cultivation, two-thirds of the households do not suffer a rice deficit and one-third face a short-fall for from one to three months. The hillside villages that depend on a combination of paddy and swidden farming have the worst food security: more than one-half of the households do not produce sufficient grain to meet their needs for four or more months each year.

The situation in Vietnam's mountains is no better. For example, in a commune in the foothills in Bac Ha district, Lao Cai province in Vietnam's Northern Mountain region studied by Sakurai *et al*. [2004], rice production falls short of consumption needs so the people must eat maize, a less favored grain, to meet their basic nutritional needs. Moreover, continuing rapid population growth will worsen the food security situation in future years unless grain production can be increased, a problem common to almost all communities in the mountainous region of Mainland Southeast Asia.

II–2 *Poverty*

Closely linked to the problem of food security is the high level of poverty in the mountains. Incomes are extremely low in most places. In the villages in northern Laos described by Yamada *et al*. [2004] the average per capita cash income was only US$30 per year in the hillside villages, US$38 per year in the mountain villages, and US$43 per year in the lowland villages. Forty-three percent of households in the hillside villages, 32 percent in the mountain villages, and 24 percent in the lowland villages are classified as being poor.

The Lisu villagers in northern Thailand described by Ongprasert and Prinz [2004] achieve somewhat higher cash income levels than the villagers in Laos, averaging US$2,736 per household. Assuming an average of 6 persons per household, this represents a per capita income of more than US$450 per year. Although high by the standards of the mountains, this is four times lower than the national average per capita income. The relative gap between per capita incomes in the mountains and the lowlands is probably even greater in most of the other countries in the region.

II–3 *Economic and Social Marginality*

Not only are the mountain area farmers poor and often hungry, they also tend to occupy marginal economic and social positions within the national systems in which they live. Many mountain people are members of ethnic minorities who do not fully participate in the social life of the nations in which they reside. Because of their cultural distinctiveness and the remoteness of their settlements they often have restricted access to educational services and often lack fluency in the national language. They tend to be ignored by national agricultural extension services although, at least in the case of the Karen in northern Thailand described by Ongprasert and Prinz [2004], some new legume crop species have been introduced by government and NGO extension workers and also private businessmen. Even, however, where extension workers are active, they may have few new technologies that are adapted to mountain conditions to offer to the farmers.

Transportation systems are much less well developed than in the lowlands and, consequently, the costs of shipping agricultural products and inputs are very high. This restricts the participation of upland farmers in the market economy on which they must increasingly depend to meet their basic survival needs. For example, as Ongprasert and Prinz [*ibid*.] point out, adoption of planting of viny legumes as a profitable cash crop by Lisu farmers in northern Thailand only occurred in villages that were readily accessible by large trucks to move the harvest to market. The more remote settlements could not profitably adopt this useful innovation.

II–4 *Environmental and Resource Constraints*

The conventional view of the mountains emphasizes the poor quality of agro-resources. Soils are considered to be thin, infertile, and easily eroded. Colder temperatures result in lower crop yields and limit production to only one crop per year, a constraint reinforced by dependence of most agricultural production on seasonal rainfall.

Certainly, these are major constraints in many parts of the mountain region. For example, the soils in Northeastern Thailand discussed in the paper by Vityakon *et al*. [2004] are highly leached, low in fertility, and subject to very high erosion rates. Annual soil loss from upland cassava and sugarcane plots reached 20 t/ha, double the US Soil Conservation Service's allowed soil loss tolerance of 10 to 12 t/ha/yr. To compensate for this loss, farmers would have to apply large quantities of expensive chemical fertilizers to maintain production levels in the upland fields. However, as Trelo-ges *et al*. [2004] suggest, income generated by upland crops in the Northeast may not be sufficient to fully cover the cost of replacing soil nutrients lost in their cultivation.

On the other hand, some of the papers offer a considerably more favorable interpretation of environmental conditions in at least some parts of the mountains. According to Ongprasert and Prinz [2004], the limestone-derived soils in their study villages in northern Thailand are highly fertile and able to sustain continuous crop cultivation for an extended period without using chemical fertilizer. These soils originally contained high levels of phosphorous and have maintained a high level of nutrient availability after 17 years of continuous cultivation. The farmers did not mention soil erosion as a problem threatening sustainability. That soil erosion is not a serious threat to agricultural sustainability of sloping land fields in Bac Ha district in Vietnam's northern mountains is asserted by Sakurai *et al*. [2004] based on their measurement of clay content and clay dispersion ratio, although they concede that over the long term, slight but continuing erosion might have reduced soil quality. In any case, the dryland fields in the higher elevation villages are beautifully terraced which would seem to represent a response by these farmers to a perceived threat of erosion. Expansion of terraced areas there, however, is limited by topographical constraints. The area that can be used for irrigated paddy fields is quite limited in most areas in the mountainous regions, as in the case in hillside villages in northwestern Laos described by Yamada *et al*. [2004].

III Driving Forces for Change in Mountain Agroecosystems

A number of forces appear to be driving changes in agricultural systems throughout the mountainous region. These include population growth, environmental and resource degradation, improved transportation and communications, expansion of the market system and economic globalization, and enforcement of government policies and regulations on land use.

III–1 *Population Growth*

Rapid population growth is a force for change everywhere in the mountain region of Mainland Southeast Asia. In Northeast Thailand, for example, as Vityakon *et al.* [2004] report, the population grew from 3 million to 18 million people in the 65 years from 1920 to 1985. This increase in the number of people, along with wide-spread adoption of cash-cropping, led to rapid clearance of forest land to open new fields in the uplands. At a more micro-level, the population density of the small Da Bac Tay ethnic minority settlement of Ban Tat in Vietnam's Northwestern Mountains described by Tran Duc Vien *et al.* [2004] increased from 10 persons/km^2 in 1954 to 75 persons/km^2 in 1999. This has forced shortening of the fallow period of the swiddens from 12 years or more to only 3 or 4 years. In northern Laos, according to Watanabe *et al.* [2004], population increase in recent years has forced shifting cultivators to shorten the period of fallow from 40 years to only 5 years.

III–2 *Environmental and Resource Degradation*

Degradation of the environment and natural resources has occurred in many parts of the mountain region. Deforestation, accelerated soil erosion, and loss of biological diversity are widespread problems, although, as the papers in this special issue show, there is a great deal of variation from site to site, with some areas showing less impact than others.

The area covered by forest has declined in many areas, often dramatically. According to Vityakon *et al.* [2004], in Kham Muang village in Northeastern Thailand, the forest area declined from 2,000 *rai* at the time when the village was first settled in 1897 to only 400 *rai* in 1987. Reduction of the number of trees has adversely affected soil quality and forced farmers to rely on purchased chemical fertilizer inputs to maintain crop productivity in their upland fields. The shrinking area for grazing cattle and buffalo has led to a decline in the number of livestock with a consequent decrease in the supply of manure that was formerly used to maintain the fertility of crop fields. It has also reduced the supply of natural forest products on which the farmers earlier relied to meet many of their basic survival needs.

Decline in the area and quality of forests has had especially serious consequences for shifting cultivators. In the mountains of northern Laos, for example, as is pointed out by Watanabe *et al.* [2004], farmers have greatly reduced the area of shifting cultivation fields planted to dry rice because of sharp declines in yields that accompanied shortening of the fallow period and the consequent worsening of competition from weeds.

III–3 *Improved Transportation and Communication Systems*

Vityakon *et al.* [2004] show how cropping systems in Northeastern Thailand have changed in response to improvements in the transportation system. In the nineteenth century, agriculture was almost exclusively subsistence-oriented. Cattle, which could transport themselves to the market in the Central Plains of Thailand, were the only source of cash. In the 1890s, completion of the first railroad to link the Northeast to Bangkok caused some farmers to begin producing small quantities of rice for the market. It was only after the construction of the Friendship Highway in the 1950s that cultivation of kenaf, followed somewhat later by cassava and sugarcane, became widespread. Similar changes in cropping systems in response to improved access to transportation have occurred throughout the mountainous region.

III–4 *Expansion of the Market System*

Expansion of the free market system, especially in the formerly centrally-planned economies of Laos and Vietnam, is an increasingly strong force for change in upland agricultural systems. For example, in northern Laos, according to Watanabe *et al*. [2004], shifting cultivators have begun to protect volunteer mulberry tree seedlings in their fallowed swiddens and to experiment with ways to propagate and intercrop this cash crop in response to development of a domestic paper processing industry and creation of export market channels. In addition to improving farm incomes, the mulberry trees substantially increase the biomass that develops in the short fallow period which, when it is burned, improves weed control in the next cropping cycle. Also in the mountains in northern Laos, according to Yamada *et al*. [2004], local people now earn a substantial share of their total cash income from the sale of forest products directly in local markets as well as to middlemen. Certain very valuable materials used in making Chinese medicines and incense are traded directly to Chinese buyers.

In Northeastern Thailand, as is discussed by Trelo-ges *et al*. [2004], farmers began to plant sugarcane in place of cassava in their upland fields after construction of a sugar mill close by their village created a reliable market. Those farmers fortunate enough to obtain a guaranteed production quota from the mill invest much more than non-quota holders in production inputs, applying chemical fertilizer at twice the rate of the latter. The non-quota holders, facing market uncertainty, often sell their immature crop to quota holders who then are responsible for managing it until the harvest. Although regularly rotating sugarcane with cassava can help to restore soil fertility that is depleted to a greater extent by cassava, farmers make decisions about whether to plant cassava or sugarcane in their upland fields primarily based on the expected market prices for these crops.

III–5 *Government Policies*

Government policies have profound impacts in many parts of the mountain region. For example, in northern Laos, as Watanabe *et al*. [2004] report, new regulations to protect forests and strictly limit clearing of new swiddens have forced shifting cultivators to shorten fallow periods and attempt to intensify production on their existing plots. As Yamada *et al*. [2004] observe, Lao government policies intended to counter environmental degradation and protect remaining forest have given little consideration to ensuring that upland people have access to natural biological resources, despite the very important role that forest products play in local livelihoods. In Thailand as well, establishment of forest reserves has limited farmers' access to land. According to Ongprasert and Prinz [2004], one of the reasons that the Lisu farmers in a village located in a forest reserve in northern Thailand adopted planting of viny legumes in their swiddens was because the vines effectively controlled weeds. They had to adopt this method of weed control after they were prohibited from using tractors to cultivate their fields by government forestry officers who were seeking to protect the forest from further encroachment.

In Northeastern Thailand, as reported by Vityakon *et al.* [2004], the shift from subsistence-oriented to commercially-oriented farming occurred in the past partially in response to government policies aimed at fostering cultivation of crops for export. Construction of an extensive road network, which was initiated by the government in the 1950s for military and security reasons, provided further impetus to commercialization by making it possible for the farmers to move their products to market quickly and cheaply.

IV Adaptive Responses

In the face of rapid changes in many dimensions of their agricultural situation, upland farmers have engaged in a number of adaptive responses. These include intensification of grain production in paddy fields (where conditions for their construction are favorable), adoption of cash cropping, exploitation of forest resources, migration, and technological innovation.

IV–1 *Intensification of Grain Production in Paddy Fields*

According to Tran Duc Vien *et al.* [2004], composite swiddening as practiced by the Da Bac Tay in Vietnam's Northwestern Mountains is more sustainable than pure shifting cultivation because the high production of the wet rice fields reduces the area needed for swiddens. In recent years, the farmers have intensified paddy production by adopting high yielding varieties and applying chemical fertilizers. The small paddy area now yields half of the grain needed to meet local consumption requirements. Although this type of intensification contributes to higher sustainability of the cropping systems there is a cost in the form of loss of biodiversity. Farmers have decreased their planting of traditional rice varieties and in some areas traditional varieties no longer exist.

Vityakon *et al.* [2004] report that in Northeastern Thailand, farmers have increased rice production by adopting improved varieties and applying chemical fertilizers. Sediments eroded into the wet rice fields from cassava and sugarcane fields cleared in formerly forested uplands also contribute to maintaining nutrient balance in the paddy fields. In northern Laos, however, Watanabe *et al.* [2004] report that excessive clearance of upland forests for swiddens is believed by villagers to have made dry season paddy cropping more difficult because of the reduced flow of water in the river that supplies irrigation water to the paddy fields.

IV–2 *Replacement of Subsistence Farming with Cash Cropping*

In many parts of the mountain region, farmers are shifting from subsistence-oriented farming to cash crop production. In northern Thailand, for example, Lisu shifting cultivators have largely abandoned growing of upland rice, their traditional subsistence crop, in favor of raising maize for sale to the market. Beginning in the 1980s, the farmers began sowing viny legumes (lablab bean, rice bean, and cowpea) as a relay crop in the maize fields. This "accelerated seasonal fallow," as it is called by Ongprasert and Prinz [2004], simultaneously restores soil fertility and generates substantial additional income. In 1997, the average gross income from sale of farm products was more than US$2,700, with almost half of that sum earned from the sale of legumes. Although planting of legumes is beneficial from an ecological standpoint, it is only sustainable as long as market prices for the beans are high. By 2001, prices for the legumes had declined by one half or more and the farmers largely ceased to plant them.

Not all farmers in the region have wholly abandoned subsistence-oriented agriculture even as they engage in greater production of cash crops, however. For example, in Northeastern Thailand, as Vityakon *et al.* [2004] show, farmers have followed a dual track strategy of mixing subsistence and commercially-oriented cropping. Growing of rice for home consumption had always been the main concern of Northeastern farmers who, until the 1950s, had only a very limited involvement in the market. However, as transportation improved and sale of crops to the market became easier, they started widespread planting of cash crops, first kenaf and later cassava and sugarcane, in the uplands. At the same time, however, they continued to devote much of their effort to producing glutinous rice in the paddy fields to meet their household subsistence needs. In fact, cash earned from the sale of upland crops is used to purchase needed inputs to maintain yields of subsistence rice in the paddy fields.

IV–3 *Exploitation of Forest Resources*

Natural biological resources, especially non-timber forest products, but also wild plants and animals collected in the farmers' fields, make a major contribution to the livelihoods of many of the upland villagers described in these papers. In the villages in northern Laos described by Yamada *et al.* [2004], natural biological resources continue to play a major role in people's livelihoods. On average, sale of natural products contributes between 11 and 61 percent of household cash income. In the case of poor households, the share of total income derived from natural biological products ranges from 33 to 61 percent of total cash income. Much of this cash is used to purchase rice to make up for local shortfalls in production. As Yamada *et al.* [*ibid.*] observe: ". . . natural biological resources are indispensable as a source of cash income to achieve food security for poor people." They further suggest that the value of these resources may increase in the future because degradation of forests in every country in the region is diminishing the supply of wild products and increasing their prices. Thus, rather than focusing exclusively on agriculture, the development strategy for this area might be better aimed at promoting a balanced mixture of agriculture and forests.

In other areas, however, deforestation and over-exploitation of natural biological resources have adversely affected farmer livelihoods. Thus, in Northeastern Thailand, according to Vityakon *et al.* [2004], pioneering farmers made heavy use of wild resources from the forest until the middle of the twentieth century, when widespread deforestation resulting from the expansion of cash cropping drastically reduced the supply of these products. Decline in the area of forest also reduced availability of grazing for livestock resulting in a serious decline in the number of cattle and buffalo. Local communities belated took steps to establish protected forests but the remaining area is too small to meet all the people's needs. It is suggested by Vityakon *et al.* [*ibid.*] that increasing the number of trees in the agricultural landscape will be an effective way to increase local self reliance and improve livelihoods.

IV–4 *Migration*

In many parts of the mountainous region farmers have traditionally coped with land scarcity and declining crop productivity by migrating to frontier areas to establish new settlements. The Hmong, who have moved southward from China into Laos, Vietnam and Thailand over the past several centuries, are the archetypical migrant shifting cultivators. According to Vityakon *et al.* [2004], the Northeastern Thai farmers also had a long-established tradition of "land pioneering" in which people from old, densely populated villages budded off to establish new settlements in the forests. In recent years, however, the forest frontier has closed in Northeastern Thailand—as it has everywhere in the uplands of Mainland Southeast Asia—so that migration to find new land is no longer an option. In the Northeast, people from overcrowded villages have migrated in large numbers to Bangkok, and even gone abroad to work as construction laborers and in the informal service sector, but this response has not occurred to any significant extent elsewhere in the region. In Vietnam, the lowlands are already overcrowded and the cities have a huge pool of unemployed workers so that there are no opportunities open to migrants from the uplands. Thus, out-migration is unlikely to be an effective adaptive strategy for upland people in the future. Solutions to their livelihood problems will have to be found *in situ*. Consequently, innovative ways to sustainably intensify agriculture in the mountains must be found, a search that the farmers have already initiated themselves.

IV–5 *Farmer Innovations*

Many of the papers reveal the great extent to which innovations in upland cropping systems are generated by the farmers themselves, often with little or no input from scientists or extension workers. For example, according to Tran Duc Vien *et al.* [2004], the composite swiddening system of the Da Bac Tay minority farmers in Vietnam's Northwestern Mountains, which is more productive and sustainable than pure shifting cultivation systems, has been practiced by farmers of this minority group for many generations. In recent years, in response to growing population pressure, they have incorporated new features into the system, including planting of canna and ginger as cash crops in the swiddens. Hmong farmers in the hilltop community in Bac Ha district studied by Sakurai *et al*. [2004] have constructed elaborate terraces on their sloping land for several generations. This technology may have been originally borrowed from China but, in recent years, construction has been accelerated due to continuing reduction in average farm size.

The use of viny legumes as an accelerated fallow by the Lisu in northern Thailand described by Ongprasert and Prinz [2004] also appears to be largely a local innovation intended to generate an additional cash crop while simultaneously improving weed control. Similarly, Lao Thung shifting cultivators in northern Laos, according to Watanabe *et al*. [2004], have begun to experiment with incorporating mulberry trees into their fallow management practices to accelerate regeneration of their fields and generate extra cash income.

A major challenge facing development policy-makers, scientists, and extension workers is to find ways to incorporate local knowledge and farmer innovations into agricultural development efforts in the uplands. Unfortunately, for many reasons, little has been done in this regard to date.

V Potential Solutions

A number of potential solutions to problems of agricultural development in the mountainous region are suggested by papers in this special issue. These include introduction of improved crop varieties, diversification and commercialization of farming systems, restoration of soil fertility, and diffusion of new technology.

V–1 *Introduction and Development of Improved Crop Varieties*

Introduction of already available high yielding varieties may offer significant opportunities to increase agricultural production, particularly in areas with fertile soils. Thus, Ongprasert and Prinz [2004] observed in an area with limestone-derived soils in northern Thailand that the first group of farmers who started using a hybrid variety enjoyed 50 percent higher yields. The following year almost all households in the village adopted the hybrid variety. However, because most plant breeding has been carried out under the controlled water and fertility conditions of lowland experimental stations, relatively few improved varieties are adapted to the more difficult conditions characteristic of the mountainous region. Varieties which are well suited to the mountain conditions, such as having tolerance to water stress, soils with low fertility, and low temperatures, should be selected and/or developed through the collaborative action of farmers and government agencies.

V–2 *Diversification and Commercialization of Farming Systems*

Diversification and commercialization of farming systems through adoption of mixed and relay cropping, introduction of tree crops such as fruits, and promotion of livestock rearing and agroforestry can help to raise incomes of farmers in the mountainous region. Numerous government and NGO projects are already promoting such solutions. For example, Watanabe *et al*. [2004] propose the introduction of paper mulberry during the fallow period of shifting cultivation in northern Laos because this type of agroforestry does not significantly degrade soil fertility and also provides farmers with cash income even from their fallow fields. Moreover, this type of fallow generates an increased quantity of biomass to be burned in the next cultivation cycle which is expected to be beneficial for weed control.

Ongprasert and Prinz [2004] describe a successful case of improving a shifting cultivation system by means of crop diversification. The cropping system of a Lisu village in northern Thailand was formerly shifting cultivation of maize interplanted with several vegetables including cucumber, wax guard, and pumpkin. At the beginning of the 1980s, villagers introduced three viny legumes, cowpea, rice bean and lablab bean and established a new cropping system. These three legumes are relay-cropped with the major crops and harvested during the dry season. This diversified cropping system fulfilled multiple functions including creating new sources of cash income, controlling weeds, and maintaining soil fertility. Unfortunately, use of this improved system was largely abandoned when the prices of legumes dropped sharply.

Access to markets is always one of the biggest constraints on crop diversification. However, transportation conditions are improving and the market for agricultural products is expanding accordingly as a consequence of national-level economic growth. Greater involvement in the market may expose the farmers to greater risks from unpredictable declines in the prices for their products. In order to mitigate the risk of price fluctuations, a wide range of diversification options should be explored.

V–3 *Restoration of Soil Fertility*

Soils in many parts of the mountainous region are already seriously degraded. Restoring fertility levels will be essential if cropping systems are to be intensified. As chemical fertilizer use is limited in the mountainous region due to its high cost and poor transportation conditions, *in-situ* restoration methods for soil fertility must be applied. At the field or plot level, as mentioned above, relay-cropping of legumes is one of the more promising methods that has already been successfully tried in many areas. Terracing and contour cultivation, as suggested by Sakurai *et al*. [2004], could minimize soil erosion and help to restore the physical and chemical property of the soil. These restoration methods, however, may only be effective under specific edaphic conditions and have limited applicability on steeply sloping land.

At the system or the watershed level there is a wide range of possible solutions. In many cases, the system consists of primary forest on the mountain tops, a complex mosaic of secondary forest, fallow land and upland fields of shifting cultivation on the slopes, and lowland paddy fields in the valley bottoms. Lateral movement of nutrients in surface and sub-surface water flows may have a significant impact on the nutrient balance of each of the subsystems within the watershed as is pointed out by Vityakon *et al*. [2004], Trelo-gas *et al*. [2004], and Tran Duc Vien *et al.* [2004]. In the composite swiddening system in the northwestern mountains of Vietnam described by Tran Duc Vien *et al*. [*ibid*.] almost all loss of N, P and K from sloping swidden fields occurs in the form of run-off. The nutrients lost from the swidden fields, however, provide more than one half of the inputs of N and P into the lowland paddy fields. It would seem that well-organized allocation of forestland, upland fields and paddy fields at the watershed level might help to create farming systems that utilize nutrients more effectively.

V–4 *Diffusion of New Technology*

In addition to improvement of crop varieties, introduction of new technology, including chemical fertilizer, herbicides, and farm machinery, could facilitate agricultural development in the mountainous region. In any case, farmers are already embracing much of the available new technology although the consequences of this are not always positive ones. For example, as is pointed out by Vityakon *et al*. [2004], farmers in Northeastern Thailand adopted chemical fertilizers and two-wheel hand tractors when they shifted from subsistence-oriented to commercially-oriented farming. Trelo-gas *et al*. [2004] point out that chemical fertilizer application for sugarcane cultivation is widely practiced in Northeast Thailand and Tran Duc Vien *et al*. [2004] indicate that chemical fertilizers are now even used to grow rice for subsistence purposes in the remote mountainous area of Northern Vietnam. Ongprasert and Prinz [2004] found that herbicide use spread in northern Thailand due to the lack of labor for manual weeding. Lack of labor also led farm mechanization there.

Shifting cultivators in Laos still seldom use chemical fertilizer, but a government research center already started experimental work on the use of a slow-releasing type of chemical fertilizer in order to mitigate the nutrient loss by erosion. Herbicide use is also likely to spread widely in the near future in parallel with changes in the cropping system from shifting cultivation to continuous cultivation.

Although diffusion of new technology is inevitable in the course of agricultural development in the mountainous region, it should be recognized that new technologies can have negative impacts. For example, cheap but toxic pesticides are still widely sold in many countries and can have serious affects on people's health. Introduction of machine-plowing instead of no tillage farming on sloping land will undoubtedly increase the risk of soil erosion.

VI Future Research Priorities

If intensification of agriculture in the mountainous region is to be done in a sustainable manner that also enhances human welfare, careful research must be done to identify opportunities and pitfalls. Key research areas relate to improvements in agronomy and agroforestry and incorporation of local knowledge and practices into national development strategies and policies for managing forest and agricultural lands.

VI–1 *Agronomic Research*

Agricultural production in the mountainous region still can be significantly increased by means of technology improvement, as was mentioned in the previous section. Development and dissemination of new crops and varieties, improvement of soil and water management, and finding more effective methods of weed control are all promising avenues for research.

Among the Mainland Southeast Asian countries on which this special issue is focused, Thailand has the longest history of agronomic research to improve mountain agriculture. The Thai government set up several research stations in the northern mountainous areas in the 1970s and initiated projects to eliminate opium growing and to introduce alternative farming options including growing of coffee, beans, vegetables, and mushrooms, animal breeding, and fish culture. In other countries, however, governments have been slower to devote resources to improvement of upland agriculture. The Lao government set up the National Agriculture and Forestry Research Institute in 1999, which is focused on the integrated agricultural development of the northern mountainous region. The Vietnamese government only established the Northern Mountainous Agriculture Research Center in 2002. These efforts to develop appropriate agricultural research institutions reflect the changes in agricultural policy goals from being exclusively production-oriented to welfare- and environment-oriented ones.

Consequently, agronomic research needs to shift its focus in order to develop technology which provide higher benefits to the mountain people and is suitable to the mountain environment, rather than just increasing production. The concept of site-specific technology is much more meaningful in the mountainous areas than in the lowlands because environmental and cultural diversity is much greater and the modification of production environment by means of large-scale irrigation and land reclamation projects is much more difficult in mountainous areas.

Employing a system perspective on agriculture is another important and effective approach in agronomic research in the mountainous areas. Efficient use of *in-situ* resources should have a high priority as a target of technology development in the mountains because of their remoteness and difficult transportation conditions. Application of chemical fertilizers and herbicides in the uplands may not be as simple or as effective as in the lowlands because of the high risk of run-off. Fertility management and weed control might be better achieved through modifications in the management of farming systems. The mosaic distribution of agricultural land and forest land within the landscape can be advantageous if we can establish a nutrient recycling system at the watershed level. Livestock may play an important role in the lateral transport of nutritients within the system that deserves further attention from researchers.

VI–2 *Agroforestry Research*

Agroforestry is often thought to be limited to the planting of annual crops among the tree seedlings on newly reforested lands. However, a new type of agroforestry based on shifting cultivation is widely emerging, in which agricultural and forest land use alternate regularly. The planting of paper mulberry in fields fallowed after shifting cultivation, as is discussed by Watanabe *et al*. [2004], is representative of this new type of agroforestry. It incorporates trees into the shifting cultivation cycle as an improved form of fallow management. By using this method, farmers can simultaneously restore soil fertility and gain economic benefits, particularly by the collection of non-timber forest products growing in the fallowed fields.

The function of fallowing in shifting cultivation has been a question that has long engaged researchers but no consensus has yet been achieved as to whether its main contribution is to fertility recovery or weed control. In this special issue, Sakurai *et al*. [2004] and Watanabe *et al*. [2004] support the latter view. It may be, however, that both answers may be correct depending on specific local conditions. This question is closely related to questions about methods for improving fallow management. If rapid fertility restoration is the goal, then legume cropping may be a suitable strategy, but if controlling weeds is the principal objective, then accelerating the regrowth of forest vegetation on fallow plots may be the best strategy for producing the large volume of biomass needed to ensure a sufficiently thorough burning to effectively destroy weeds.

The uses of secondary forest that emerges after shifting cultivation is also an emerging research issue. Secondary forest has generally been thought of only as deteriorated forest or recovering forest, but it has some functions which primary forest does not have. Secondary forest provides local people with a wide range of non-timber forest products, as Yamada *et al*. [2004] found. These products are mostly collected from light-demanding pioneer species which seldom exist in primary forest. This suggests not only the economic importance but also the biological significance of secondary forest. Secondary forest may have lower species diversity than primary forest, but it undoubtedly contributes to increasing the overall biodiversity of a watershed.

Yamada *et al*. [2004] suggest that the degradation of natural environment has accelerated in every country in the mountainous region and that this has resulted in a growing scarcity of natural biological resources. This increases the economic value of both remaining areas of primary forest and of secondary forests in the region. Non-timber forest products are a major component in the growing cross-border trade between China and Southeast Asian countries. Research on cultivation of non-timber forest product is a high priority topic in regard to developing systems of improved fallow management to make shifting cultivation more economically and environmentally sustainable.

VI–3 *Role of Local Knowledge and Practices in National Development Strategies and Land Use Policies*

The mountainous region is characterized by great environmental and cultural diversity. This suggests the difficulty of applying standardized development policies to this region and the importance to incorporating local knowledge and practices into national development policy. All too often, national policies fail to take local realities into sufficient account. For example, collection of natural biological resources based on local knowledge plays a significant role in income generation in Northwestern Laos, as Yamada *et al*. [2004] describe, but this role is largely ignored in Lao government policies for development and management of forest lands. Similarly, as is pointed out by Vityakon *et al*. [2004], Thai national policies to promote production of export crops in the Northeast did not take into account the loss of valuable natural products on which local people depended for many of their livelihood needs that resulted from conversion of forest into cropland.

Land and forest resources management are key issues of national development strategies in the mountainous region because these resources are essential for both economic and environmental purposes. There is a rich store of local knowledge about how to best manage these resources but this knowledge differs from village to village and by ethnic group. Developing a more comprehensive understanding of such local knowledge is an important research priority because it can provide the basis for more effective and efficient implementation of modern regulations by national governments and reduce the potential for conflict between local and national interests.

Conclusion

The people of the mountainous region of Mainland Southeast Asia face growing difficulties in making their livelihood. Developing agriculture in ways that will increase productivity while also meeting social needs and protecting the environment is an urgent task. Intensification of upland farming systems is a key element of agricultural development in the mountainous region. The papers in this special issue present considerable information on the causes, mechanisms, and consequences of some efforts at intensification in many different localities in the mountainous region. They suggest that, even in the difficult agricultural environment of the mountains, intensification is possible and can result in greatly increased productivity. They also reveal that it can have adverse environmental consequences when the technical means employed are not well adapted to local conditions. They also show that adoption of sustainable farming systems is as much constrained by economic, social, and policy factors as it is by availability of technology and environmental limitations. Perhaps most importantly, these case studies illustrate the very great extent to which local conditions limit the available options for agricultural development in different areas in the mountainous region. It would appear that no single solution can be found to the problem of sustainable management of agro-resources there and that, consequently, research needs to focus on understanding how specific farming systems function in specific local contexts. Incorporation of such site specific knowledge into national development policies remains a major unresolved problem.

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書　評

植木真理子.『経営技術の国際移転と人材育成──日タイ合弁自動車企業の実証分析』文眞堂，2002，185p.

Ⅰ

本書は，多国籍企業のグローバル経営の発展方向性を指し示そうとする意欲的な研究の成果である。日タイ合弁自動車企業を対象とした実証分析を通じて，筆者は，日本的経営技術の移転と現地人材の育成が競争優位獲得の鍵になると主張している。定量的分析と定性的分析を組み合わせることで，双方の分析方法の不足点を補い，より包括的・体系的な分析が試みられている。

グローバル競争の時代をいかに生き抜くのか。これは，組織の規模を問わず多くの企業にとって共通の課題であるということに異論はないだろう。企業の存在意義は，そもそも顧客価値を生み出すことができるかどうかに掛かっている。究極的には，どれだけの最終顧客を獲得できるのかということが，製品・サービスの生産・供給のために編成されるグローバルな価値連鎖網の生命線となる。個別の事業組織には，そのネットワークの発展に自らの強みを活かした貢献が期待される。多国籍企業は，様々な国と地域に資本を投下して，グローバルに価値連鎖網を構築してきた。今日では，特に，文化的・経済的な背景の異なる地域でそれぞれ操業する組織間ネットワークの最適化が重要な課題となっている。そのネットワークの拠点となるべき組織をどのような人的資源の組み合わせによって編成するのか，また，その人的資源をどのように開発していけば良いのか。本書で取り組んでいるのはそういう問題である。

本研究における筆者の論旨は次の通りである。アセアン市場において日タイ合弁自動車会社が輸出市場志向型で競争優位を獲得するためには，現地人材の育成を促進する必要がある。そして，彼らを高いポジションへ登用することにより，コミットメントの程度を高めなければならない。現地人材を高いポジションに登用することにより，日タイ合弁企業は，地域の経営環境の変化への自律的な対応能力を構築すると共に，グローバルな経営の最適化を実現することができるというのである。

Ⅱ

ここでは，まず，簡単に本書の構成と内容について紹介する。

本書は，7つの章から構成されている。第1章では，序論として本研究が採り上げる問題の所在とその背景，研究の目的と意義，基本概念の説明，そして，研究の方法論が提示されている。日本の多国籍企業は，欧米への拠点設置の場合と同じく，東南アジアにおいても，現地それぞれの条件への適応を重視しながら，日本型経営の移転と定着を進めてきている。1980年代から加速した日タイ合弁の設立には，2億人といわれるアセアン市場の拡大という背景がある。タイ投資委員会（BOI）は，2001年に認可した投資プロジェクトは275件，総額590億バーツであり，ここ数年日本が1位であると指摘している。また，タイ銀行によると，日本からタイへの直接投資額は12億米ドル（2001年）であり，外国からタイへの直接投資の45％を占めているという［日本労働研究機構　2002］。タイ国における産業育成の方針は，1980年代以降，国内需要の落ち込みにより，輸入代替型から輸出市場志向型へと転換した。さらには，1985年プラザ合意以降，1990年代は，日本やアジアNISEから輸出市場志向の直接投資が多く流入している。ここで取り上げられている日タイ合弁自動車企業もその例外ではない。今後は，各国政府による関係部品の国産化要求が緩和し，加えて，AFTA施行による貿易・投資の自由化に伴い，アセアン域内での企業間協働が激しさを増していくという見通しがある。

本書は，以上の社会状況を踏まえ，次のような問題を提起する。すなわち，「これまで非競争的な環境下にあった日タイ合弁自動車企業が新たなグローバル競争の波に直面していく中で，経営技術移転や人材育成の取り組みはどのように変化して

きているのだろうか」。筆者はこの変革のプロセスの分析に取り組むのである。

また本研究の意義として，筆者が指摘しているのは，発展途上国への技術移転モデルを構築すること，そして，現地人材の開発を行うことの有効性を提示することである。さらには，「本国親会社との国際化戦略に連動して，タイ現地法人の戦略的な重要性が高いほど，経営技術移転や人材育成の取り組みが積極的に展開されることを明らかにしていく」と述べ，「本国親会社の国際化戦略に連動した海外子会社の戦略的な重要性の違いによって現地中間管理者の職務満足度や仕事及び会社へのコミットメントの程度が異なるかどうかを明らかにした研究は未だに見られない」と重ねて，本研究の意義を説いている。

第２章では，まず，タイ自動車産業の発展を工業化の歴史の中で整理している。その歴史の中で，日本の親会社による国際化戦略がどのように展開し、現地法人の戦略的位置づけがどのように移行していったのか，特にタイ通貨危機後の展開として輸出市場志向型への転換によりタイ現地法人への新たな経営技術移転が行われた歴史的な流れを整理して説明している。

第３章では，経営技術の国際移転に関する研究をはじめ，経営の現地化と人材育成に関わる先行研究について批判的に整理している。特に，タイ現地法人の自律性を高めるためには，現地人材の登用を進め知識創造を促進させることに大きな意義があると言っている。

第４章から第７章においては，提示した仮説について，筆者自身が1997年と1999年にかけて実施した本社と現地法人でのアンケート調査とケースの記述が行われ，続いてその検証と考察がなされている。

第４章から第６章に至る仮説の設定とその検証の結果は，次の通りである。まず仮説１の検証結果では，「輸出市場志向型戦略の企業は長期雇用の安定性を重視し，生産・品質管理を主とする組織・管理関係の日本型経営技術を積極的に移転していることが明らかにされた。〈中略〉今後，輸出市場志向型戦略に転換する日タイ合弁自動車企業が自律創造的な経営を展開していくためには，それを達成するための条件として，まず日本企業の一番強みとする生産・品質管理手法の積極的な移転努力が必要であり，次に経営技術を現地へ定着させるための人材育成が重要である」と指摘する。仮説２の検証結果では，「輸出市場志向型戦略の企業の方が人材育成に積極的であり，それが高い職務満足度に影響することを明らかにした。しかし，人的資源の開発は，全体的な傾向としてレベルが低い。したがって，場当たり的な人材育成ではなく，企業の長期的ビジョンに基づく人材育成システムの構築が必要になっている」と指摘している。続いて仮説３の検証結果として，「仕事・会社へのコミットメントと長期雇用の安定性の相関が高いことがわかり，長期にわたる技能や経営ノウハウの蓄積が自律創造的な参画型経営に極めて有効であることを示している」と述べている。さらには，まとめとして，「以上３つの仮説検証によって，本国親会社の国際化戦略に連動したタイ現地法人の戦略的重要性の違いが，経営技術の移転や人材育成の取り組みやタイ人中間管理者の職務満足度の差に対して影響を与えることを明らかにした」と結論づけた。

Ⅲ

では，本書の評価について検討していくことにしよう。本研究の最も大きな意義とは，本国親会社の国際化戦略に連動する現地子会社の戦略的位置づけの違いにより，日本的経営技術の移転度にどのような違いがあるのかということを実証研究と事例研究を併用しながら重厚に分析・考察したということであろう。さらに，詳しくいえば，輸出市場志向型と国内市場志向型の企業の間では，なぜ日本的経営技術の移転度が異なり，さらには人材育成についての取り組みの深度が異なるのかということに根拠付けが行われた。また，筆者は、国際技術移転論に新しい論点を提示している。それは，「仕事および会社に対するコミットメントの高い現地中間管理者は，日本型経営技術のコア要素である長期雇用の安定性を高く評価する」という指摘である。筆者が指摘しているように，従来から定説となっていたのは，「ホワイトカラー管理

者は日本型経営技術を低く受容する」という見解であり，筆者による指摘はこの研究分野に新しい研究課題を投げかけていると言えよう。

また本書では，貿易・投資の自由化に向かうアセアン市場の拠点として機能する現地法人では、タイ人中間管理者の育成が急務であるという課題を提起している。ところで，ここではどのような人材像を想定しているのだろうか。文脈から推定することができるのは，日本人管理者の代替要員として機能し，日本的経営手法を現地子会社へ移植することのできるような現地人材の育成を目標にしているということである。従来，日本企業が競争優位の要因としてきたビジネス・プロセス全般に及ぶTQCの徹底を日本人に代わって遂行できる管理者を目標としているようである。

現在，タイの現地人材の高いポジションへの登用が進まない理由として，筆者は，「インタビューで聞く限り，知識創造を組織的に実践し，主導できる有能なタイ人管理者が未だ少なく，彼らの多くには，派遣日本人管理者に依存し責任を回避する行動も見られる」という指摘を根拠としている。かつて渡辺［1989］が，日本的経営技術の受容について，日本人トレーナーとアメリカ人トレイニーとの間にある認識のずれについて指摘したことがあった。すなわち，「日本人は，自分たちのやり方が分かってもらえないと考えるのに対し，アメリカ人は分かっているし，受容していると考えるという相互の認識のずれがみられる」というものである。これは，日本人管理者（訓練側）が，従業員（被訓練側）の受容力・理解力を過小評価する傾向にあるのではないかという指摘である。筆者のインタビューに基づいた記述にも同様の傾向が見て取れるのではないだろうか。すなわち，日本人管理者が，タイ人中間管理者の日本的経営技術に対する受容力を過小評価しているのではないかということである。野中［1992］が指摘するように，暗黙知の形式化と分節化のプロセスにおいて重要な役割を果たすのは，人と人との濃密かつ継続的な対話である。そして，その前提となるのは，個人間の信頼に基づく対話的思考である。もし，日本人管理者のタイ人中間管理者への評価が過小なものであり，両者の間に重厚な信頼関係が構築されていないとすれば，有効な知識創造のプロセスが現地法人に実現するとは考えにくい。本書についても，渡辺［1989］のような本国管理者と現地人材との認識のずれに関する分析が付け加われば，より重厚な議論になることは間違いないだろう。

さらに筆者は，「輸出市場志向型企業が，国内市場志向型企業に比べて経営技術移転や人材育成に対する取り組みに積極的であり，現地中間管理者による経営参画の程度が高い」という指摘を行っている。これは，調査を行った日タイ合弁自動車企業に関する統計的な経営分析に基づいて提示された見解である。これは，先行的に輸出市場志向型に転換したいくつかの企業の経験から導きだされた結論である。しかし，このことは，今後輸出市場志向型へと転換する他の企業の成功条件として当てはまると言えるのかどうか，疑問が残る。過去に他の組織が成し遂げた成功が，他の組織のそれを導くことになると言えるのかどうか。このように捉えれば，「今後AFTA施行により自由貿易体制が整備され，アセアン地域内における国際分業体制が構築される中，その中心となるタイ現地法人の高度な役割が期待されるため，経営技術移転や人材育成を継続的に実施していくことが今後ますます重要になっていく」という筆者の指摘はいくらか正直過ぎるのではないだろうか。この指摘の真偽は，将来の各企業の成功を見守ることで確かめられることになるだろう。

最後に，もう一つ疑問を提起しておきたい。それは，日本的経営技術が，これからも競争優位の源泉となりうるのかどうかという問いである。筆者は，現地人材の登用により日本的経営システムの特徴である生産プロセス全域でのTQCの効率的な遂行が，競争優位に結びつくとしている。たしかに，製品・サービスの品質の高さは，競争優位の重要な源泉である。また，TQCを生産プロセスで精緻に遂行する組織能力は，日本企業の重要なコンピタンスであった。しかし，競争優位の源泉となるのは品質管理ばかりではない。製品や生産プロセスの質的側面への顧客ニーズに過剰に適応したことにより，それ以外の顧客ニーズに適応する能力が相殺されてしまう可能性もあるだろう。

グローバル競争の時代，市場への新規参入者が増える中で，どのような価値が市場から選択されるのか。まだ，その答えは明確には示されていない。それゆえに，日本的経営技術の移転を競争優位の源泉として決めて掛かることは，早計であると言わざるをえない。そういう意味で，これからの日本企業のグローバル経営には，多くの課題が残されていると言えよう。

以上のようにいくつかの疑問点を指摘することができる。しかし，全体として，この研究は，グローバル経営における人的資源管理の研究と実務に多くの問題を提起し，堅実な処方箋を提供することができるだろう。

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