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Developing a methodology for identifying, mapping and potentially monitoring the distribution of general farming system types in Vietnam's northern mountain region

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Abstract

This study tests a method to identify and map the spatial distribution of general farming system types in five districts of the northern mountain region (NMR) of Vietnam. Over the last 50 years the NMR has suffered from a large loss of forest cover, often blamed on the swidden farming systems that are found in the mountains. As a result different programs have been put forward to change local land use practices: to decrease the amount of swidden land, "sedentarize" farmers responsible for practicing swidden agriculture, and introduce new farming systems. However, some researchers have identified one type of swidden farming system, composite swiddening, as ecologically more stable, causing little net deforestation and less environmental degradation than other farming systems in the NMR. To date no study has identified how widespread this or other types of farming systems are in the NMR. This study makes use of geographic data for five districts in the NMR within a GIS, combined with field checking, to characterize, identify and map the spatial distribution of the general farming system types, including composite swiddening, by commune for these districts. The results of the mapping indicate that there are few communes where a single farming system type is found. As these districts are spread over five provinces, the results reinforce the view that in Vietnam's

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NMR, farming system types vary down to below the commune level. An 80% agreement between the results shown on the map and field checking resulted from an examination of 19 communes in the districts mapped. A comparison was done of 2000 data to 1992 data for one district. An analysis of the communes' farming systems for 1992 and for 2000 indicate that permanent agriculture farming systems of both rice paddy agriculture and permanent upland agriculture are appearing and replacing swiddening systems.

Keywords: Farming system distribution; Composite swidden; GIS modelling; Remote sensing; Vietnam

1. Introduction

Degradation of natural resources is a global problem. In Vietnam the uplands are the ecological zone where the threats are most serious. The uplands consist of hills, highlands, and plateaus, and occupy 24.4 million hectares (74%) of the country's total area, most of which (20 million hectares) have slopes greater than 15°, while the remainder have slopes between 8° and 15°. The uplands are also the home of some 24 million people and essentially all of the ethnic minorities live there (Cuc et al., 1990). The condition of natural resources in these sloping lands is alarming. In the early 1990s, the remaining forest area was 9.4 million hectares, while 13.5 million hectares were considered barren (Phong, 1993). De Koninck (1999) notes that this condition persisted into the late 1990s as the annual national rate of deforestation in 1997 remained between 3% and 6%.

In large areas of the uplands, swidden agriculture (also known as slash-and-burn or shifting cultivation) is thought to constitute the most serious threat to the natural environment (Fox et al., 2000; Tachibana et al., 2001). This viewpoint is found in many places throughout the world (Myers, 1993; Riswan and Hartanti, 1996) and across all of Southeast Asia, causing it to be outlawed at various times in almost every country in the region (Padoch and Coffey, 2003). The Vietnamese government has subscribed to this belief (Dang, 1991; Morrison and Dubois, 1998) and has repeatedly attempted to prohibit its practice through a major program intended to "sedentarize" upland populations (Tran, 2003). Despite heavy expenditures, it is believed that this program has enjoyed little success, because it is unable to provide the swiddeners with alternative methods of earning livelihoods that are commercially viable, culturally acceptable, and ecologically sustainable (Tran, 1998).

The composite swiddening agriculture system (CSA) is an alternative farming system that appears to overcome these problems. It is a relatively sustainable type of land use practiced by some ethnic minority groups in the Northern Mountain Region (NMR). It is practiced by several ethnic minority groups in Da Bac district, Hoa Binh province, which is one of the sites where this research was conducted. The farming system integrates both permanent rice paddy fields and rotating swidden plots into a single household farming system (Rambo, 1998). This type of land use has existed for centuries not only in the mountains of northern Vietnam, but also in South-western China (Rambo, 1998), Nan province in Northern Thailand

(Kunstadter, 1978; Kyuma and Pairintra, 1983), in the Ifugao of the Cordillera in the Philippines (Prill-Brett, 1986), and in Luang Prabang province of Lao PDR (Gillogly et al., 1990). Composite swiddening is a relatively diverse, dynamic and flexible system, and seems to hold considerable potential for intensification (Tran and Pham, 1996; Rambo, 1998). Therefore, the distribution of this and the other major types of farming systems in the NMR needs to be known for planning and developing more sustainable agriculture systems. However, although it is recognized that there is a large diversity of farming system types and livelihood strategies in the NMR (Donovan et al., 1997; Jamieson et al., 1998; Cuc and Rambo, 2001; Castella et al., 2002a,c), the spatial extent of the farming system types at the commune level is not known.

This same limitation is noted regarding the spatial extent of swidden farming systems on a regional basis. Padoch and Coffey (2003), while discussing the changing situation vis-à-vis swiddening on a regional basis, note that swidden farming systems are "temporally and spatially complex" and are "typically represented in the landscape by a large number of distinct landscape features, each of which may be changing and easily confused with other land uses." They argue that because of this, land associated with swidden farming systems is miscalculated and the true extent of swidden farming systems in the region is not known and may be impossible to know. At the same time, though, they argue that having an accurate picture of the scale and pace of changes in swidden farming systems on a regional basis is important, not only to better explain why the changes are taking place, but also to be able to predict possible consequences of the change from swiddening systems to other agricultural systems.

The hypothesis grounding this study is that it is possible to use a limited amount of available spatial information combined with knowledge of the land cover "footprints" that result from the general farming system types in the NMR to identify the spatial extent of the major farming systems by commune in five districts of the NMR of Vietnam. This study begins from the recognition that the land cover of a village is a result of the agricultural processes of the village's population as a whole. The study seeks to show that by understanding how the processes lead to different landscape patterns, a GIS model that identifies the spatial patterns across the landscape can be built and a map identifying the dominant general farming system types by commune can be made.

Laney (2004) found that there is a farmer-level process-pattern linkage that can predict the land cover at the village level. As farmers' practices change, the land cover also changes. Walker (2003) explored agricultural processes at the farm level to better understand the resulting deforestation patterns in the Amazon. In both cases, the household level process is aggregated up to explain the land cover pattern. In this study, the authors draw on their understanding of the household and village level practices, or processes, that are associated with different general farming system types in the communes of the NMR in conjunction with geographic variables, to identify and map the distribution of the general farming system types across five districts in the NMR. The GIS model that is developed to guide the mapping uses satellite derived land cover data from 1999 and 2000, field checked during February, March and April of 2003. For one district where data were available the resulting

map was compared to a map of general farming system types by commune for 1992 that was created using the same methodology.

2. Methods and mapping

2.1. Defining the farming system types and linking the processes to the patterns

Fig. 1 shows the steps and procedures of the mapping exercise. The first step is to identify the farmer's practices, the processes, with each of the general farming systems found in the NMR. For the purposes of this exercise the general farming systems found in the NMR were divided into two main categories: pure farming system types and mixed farming system types. Pure farming system types are defined as farming systems solely made up of either one of two upland types: rotational swidden systems and permanent upland (dry land) agriculture systems, or one lowland type: rice paddy systems. Mixed farming systems incorporate both upland and lowland types in the same farming ''system'' in the same commune. From this division, a list of the different general farming system types that could be found by commune include the above ''pure'' systems and the following ''mixed'' systems: rice paddy and permanent upland agriculture; permanent upland and rotational swidden agriculture; permanent upland, rotational swidden and rice paddy agriculture; and composite swidden agriculture (CSA). While other studies do not necessarily divide the general farming system types into ''pure'' and ''mixed'' they do divide the major farming systems in the NMR into similar categories. For example Hung et al. (2001) divide the farming systems they studied into five main categories, swidden, paddy rice, permanent dry land, home garden, tree gardens, and Fatoux et al. (2002) in their study in Bac Kan Province, also divide farming systems into five categories that can be grouped under the more general categories of swidden, composite swidden, and permanent agriculture.

The farming practices, or processes, associated with each of these general farming system types were identified from a review of the literature and from the authors' field experiences. The land cover that results from the processes associated with each of the general farming system types was then specified (Table 1).

2.2. Land cover mapping

A list of spatial data that could be used to create a GIS overlay model to map where general farming system types are found in the NMR is potentially large. However, the current study was limited by 'financial constraints' to spatial data already available at the Hanoi Agricultural University (HAU). Digital data available included elevation contours; river and stream; road and path; political boundaries (province, district and commune); and general land cover information. Elevation, river and stream, road and path, and boundary data were in vector format. Land cover information was derived from satellite imagery for 1999–2000, and for one district for 1992. All of the data were transformed into the same datum, projection and

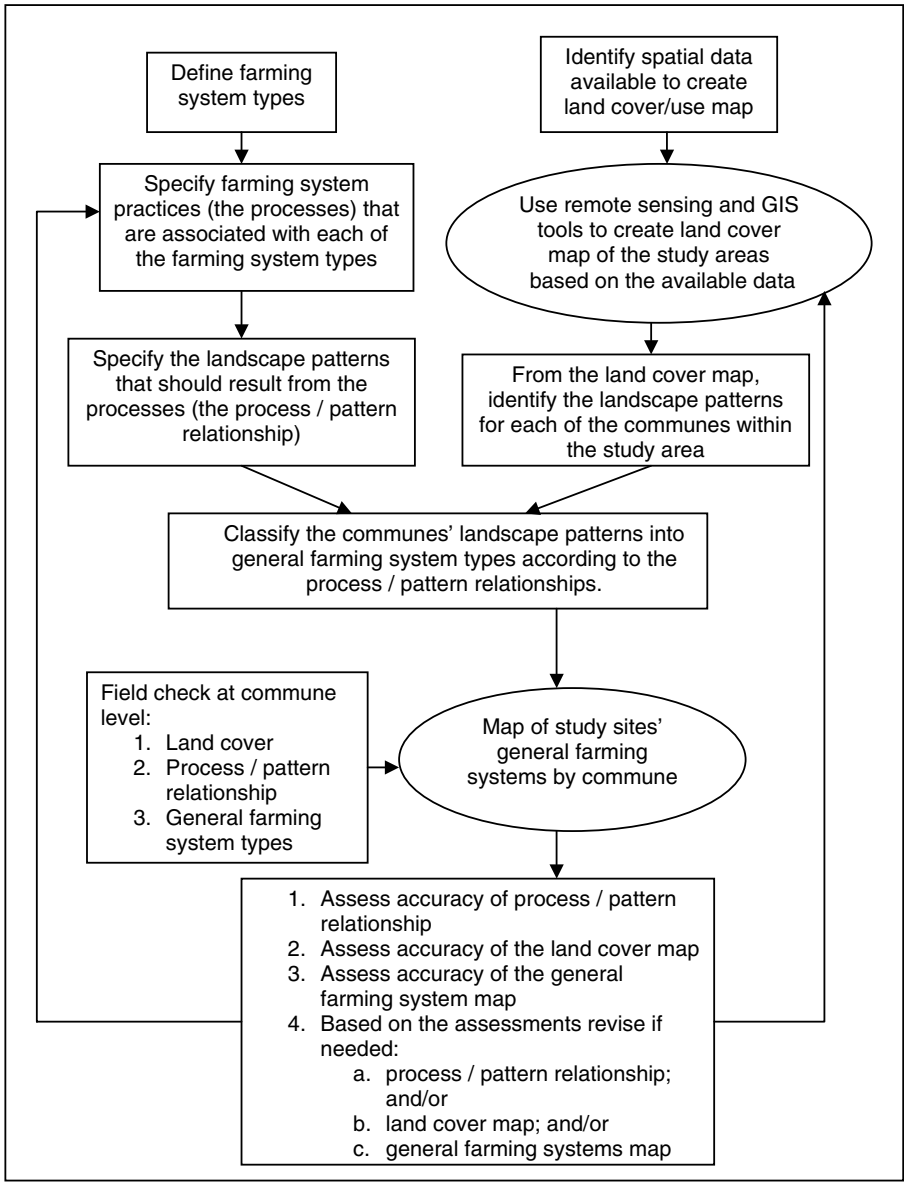

Fig. 1. Steps and procedures.

coordinate system, checked for accuracy and edited as needed. A digital elevation model, slope model and aspect model were derived from the twenty meter contour data.

In order to classify land cover for the northern mountain region of Vietnam, Landsat TM satellite images were obtained for two periods. One set is for 1999

Table 1
Farming system type, farmer practices, and land cover patterns

General village level farming system type	General processes followed by farmers at the village level	Land cover pattern at the commune level
Pure systems		
Rotational swidden system (RSA)	>80% of households clear fields from fallow land or forested areas annually and plant crops on these fields (upland rice, maize, cassava, or other crops). Fields cleared and used for 1 to 3 years in a row; fallowed for 3 or more years. Fields' slopes range from 5° to 45°. Almost no permanent rice paddy or upland fields	Patches of small (0.3 ha) to medium (10 ha) bare ground (indicators of upland ag.) interspersed with patches of regrowth (grass, bush, bamboo, small to medium size trees) or forest
Permanent rice paddy system (PRP)	>80% of households cultivate rice paddies. Almost no rotational or permanent upland agriculture	Large areas of rice paddy (greater than 20 continuous hectares); little or no bare ground; large continuous areas of grass, bush, bamboo, small to medium size trees or forest
Permanent upland agriculture system (PUA)	>80% of households cultivate fields with slopes ranging from 5° to 45°. Fields used on a yearly basis, or almost every year. No fallow period. Almost no rotational swidden or permanent rice paddy	Large continuous areas of bare ground (>10 ha) with little or no regrowth; large continuous areas of grass, bush, bamboo, trees and/or forest
Mixed systems		
Systems with PRP and PUA	Households cultivate permanent rice paddy and upland agriculture fields. Almost no swidden	Large areas of rice paddy (>20 continuous hectares) and large continuous areas bare ground (>10 ha) with little or no regrowth; large continuous areas of grass, bush, bamboo, trees and/or forest

(*continued on next page*)

Table 1 (*continued*)

General village level farming system type	General processes followed by farmers at the village level	Land cover pattern at the commune level
Systems with PUA and RSA	Households cultivate permanent upland agriculture fields and rotational swidden fields. Almost no rice paddy	Large continuous areas of bare ground (>10 ha) with little or no regrowth; other areas in the commune have patches of small to medium size bare ground, interspersed with patches of regrowth or trees/forest
Systems with PUA, PRP and RSA (can be CSA)	Households cultivate permanent rice paddy fields, permanent upland agriculture fields, and rotational swidden fields. No one form of ag. accounts for more than 70% and no one form of ag. accounts for less than 10% of the cultivation practices. Some households can practice CSA	Different areas within the same commune have: rice paddy (from 0.3 ha to >20 ha); large continuous areas of bare ground (>10 ha); patches of small to medium size bare ground, interspersed with patches of regrowth or trees/forest
CSA	Households simultaneously cultivate both permanent rice paddy and rotational swidden fields. Households also collect non-timber and timber products from the fallow and forest areas	Areas of small to medium continuous rice paddy (0.3–20 ha). Close by are patches of small to medium size bare ground areas, interspersed with patches of regrowth or trees/forest

Table 2
Rules for identifying land cover classes, making use of slope and land cover from satellite image interpretation

General Land Cover Class	Rule
Rice paddy agriculture	0–5° + open areas of grass or bare soil
Upland agriculture	slope 5–45° + open areas of grass or bare soil
Upland agriculture (steep)	slope >45° + open areas of grass or bare soil
Regrowth vegetation	slope 0–5° or 5–45° or >45° + mixed small tree, bush, bamboo, grass areas
Trees/Forest	slope 0–5° or 5–45° or >45° + denser trees
Water	slope 0–5° or 5–45° or >45° + water
Other	0–5° or 5–45° or>45° + other land cover

and 2000 from November, December and January (the dry season), the second set, covering one district, is from November 1992. All the images were registered to the same datum, projection and coordinate system as the vector data. The general land cover classes of dense vegetation (tall trees and/or forest areas), less dense vegetation (short trees, bush, bamboo, and mixed grass, all of which are likely regrowth after clearing), bare soil (most likely active agriculture areas), and water were derived from the imagery. The classification was refined by overlaying it on the slope model in order to better determine the rice paddy from the upland agriculture fields. The rules used to delineate these land cover types are found in Table 2. A more extensive discussion of the methods used to register the images and classify the land cover can be found in Leisz et al. (2001).

Knowing that rice paddy areas need a water source, an overlay analysis of the stream and river layer on the land cover classes was done. Rice paddy areas were checked to make sure that a water source flowed into the area, went through the area, or flowed out of the area. If this was not the case, the class was changed to upland agriculture. Integrating a soil map would have provided better delineation between some of the land cover classes (e.g. between rice paddy areas and upland agriculture areas on flat land). However, an accurate commune level digital soil map was not available. To compensate for this soil scientists at HAU suggested that the study initially focus on the northwest part of the NMR where the soil characteristics are generally known to be adequate to support rice paddy cultivation in the valley bottoms.

2.3. Land cover pattern analysis

As already noted the study area was initially limited to the provinces found in the north-western part of the NMR. Good quality satellite imagery was not available for Lai Chau province, so this province was excluded from the study. The districts chosen as study locations from the five remaining north-western NMR provinces are Sa Pa, Lao Cai province, Van Chan, Yen Bai province, Thanh Son, Phu Tho province, Da Bac, Hoa Binh province, and Bac Yen, Son La province (Fig. 2). Da Bac district was purposely chosen for this study as it is a long-term research site for HAU. The other districts were randomly chosen from the districts within each individual province.

Fig. 2. Districts included in the study.

Originally the aim of this study was to characterize the farming system type at the village level. However, the government of Vietnam has not published official boundaries at the village level (Roche and Michaud, 2000), making it difficult to accurately distinguish the village farming system type at the village level using the spatial methodologies followed here. Therefore, the unit of analysis for this study is the commune. In order to link the farming system with the expected landscape pattern at the commune level, the land cover pattern in each commune in each district was characterized using FRAGSTATS software, which is a spatial pattern analysis program that quantifies the areal extent and spatial configuration of patterns within a user defined landscape (McGarigal and Marks, 1995). The landscape metrics derived at the class level that are used to characterize the landscape pattern for each commune are: the percentage of land in each class; the ratio of upland field area to rice paddy field area; and the normalized landscape shape index (NLSI). As described in FRAGSTATS' documentation the NLSI provides a simple measure of class aggregation or clumpiness ranging from 0 when the class is totally aggregated, to 1 when the class is maximally disaggregated. These metrics were noted for each commune in each district within the study.

3. Identifying general farming system types by commune

The initial rules for using the landscape metrics to classify commune level general farming system types in the five districts were derived from five communes in Da Bac district (Table 3). A visual analysis of the landscape pattern for each commune was also done. Muong Tuong commune (Fig. 3(a)) is an example of a commune dominated by permanent upland agriculture. A visual analysis of its landscape pattern corresponds to the landscape metrics, which indicate that over half the area is upland agricultural fields, the ratio of upland agriculture fields to rice paddy is 11:1, and the upland fields are aggregated.

Tu Ly commune's landscape pattern (Fig. 3(b)) is an example of a commune with both large continuous areas of rice paddy, and permanent upland agriculture. The landscape metrics for Tu Ly suggest a similar interpretation: total agricultural fields make up 33% of the area, the ratio of upland agriculture to rice paddy is 1:1, and both types of fields are aggregated with NLSI metrics of less than 0.20. Both Giap Dat and Tan Minh are communes with predominantly composite swidden agriculture farming systems. The communes' landscapes (Figs. 3(c) and (d)) have small to medium size areas of rice paddy and scattered upland fields, swidden fields, within close proximity of rice paddy areas, and large areas of fallow regrowth. The metrics for these two communes reinforce this interpretation: the percent of area devoted to agriculture is less than 20%, indicating that there is a large area of land under fallow regrowth; the ratio of upland agriculture to rice paddy is more than 1:1, but not so large to indicate that upland agriculture is more important than paddy rice cultivation; and the NLSI for both upland agriculture and paddy rice is greater than 0.28, indicating that both the paddy rice and the upland crops are grown in fields that are disaggregated.

Last, Doan Ket has a landscape that suggests there are areas of permanent upland agriculture and rice paddy, and areas of composite swiddening in the commune (Fig. 3(e)). In the middle of Doan Ket the landscape looks similar to that in Tu Ly. However, in parts of the northeast and eastern parts of Doan Ket, the landscape pattern includes large areas of fallow regrowth, small, scattered, rice paddy and small scattered upland fields, indicating composite swiddening in these areas. This is not surprising, as Doan Ket is bordered by Tan Minh to the northeast. The metrics, also, fall between those of composite swiddening and permanent agriculture. The percent of area under agriculture is 28%, the ratio of upland agriculture fields to rice paddy is 2:1, and the NLSI for upland agriculture is 0.22, while that for rice paddy is 0.28. These metrics indicate the upland agriculture and rice paddy areas are both somewhat aggregated. Comparing the metrics for Doan Ket with the visual analysis suggests that in communes with general farming system types that are mixed and made up of a mix of permanent and swidden/composite swidden systems, the visual analysis can better separate between the permanent and the swidden agriculture areas than the landscape metrics, because the metrics do not allow one to "see" the spread of the land cover types over the landscape.

Using rules based on the landscape metrics and visual interpretation guidelines derived from these five cases the general farming system types of all of the communes

Table 3
General farming system and landscape metrics for five "initial" communes

Commune	General farming system type	% of landscape under agriculture	Ratio upland agriculture to rice paddy	NLSI upland	NLSI rice paddy
Muong Tuong	(Pure) Permanent upland	52.7	11:1	0.12	0.52
Doan Ket	(Mixed) permanent upland, permanent rice paddy, and composite swidden agriculture	28.2	2:1	0.22	0.28
Tu Ly	(Mixed) permanent upland and rice paddy	32.8	1:1	0.19	0.14
Giap Dat	(Mixed) composite swidden agriculture	17.2	2:1	0.29	0.36
Tan Minh	(Mixed) composite swidden agriculture	13.2	3:1	0.32	0.37

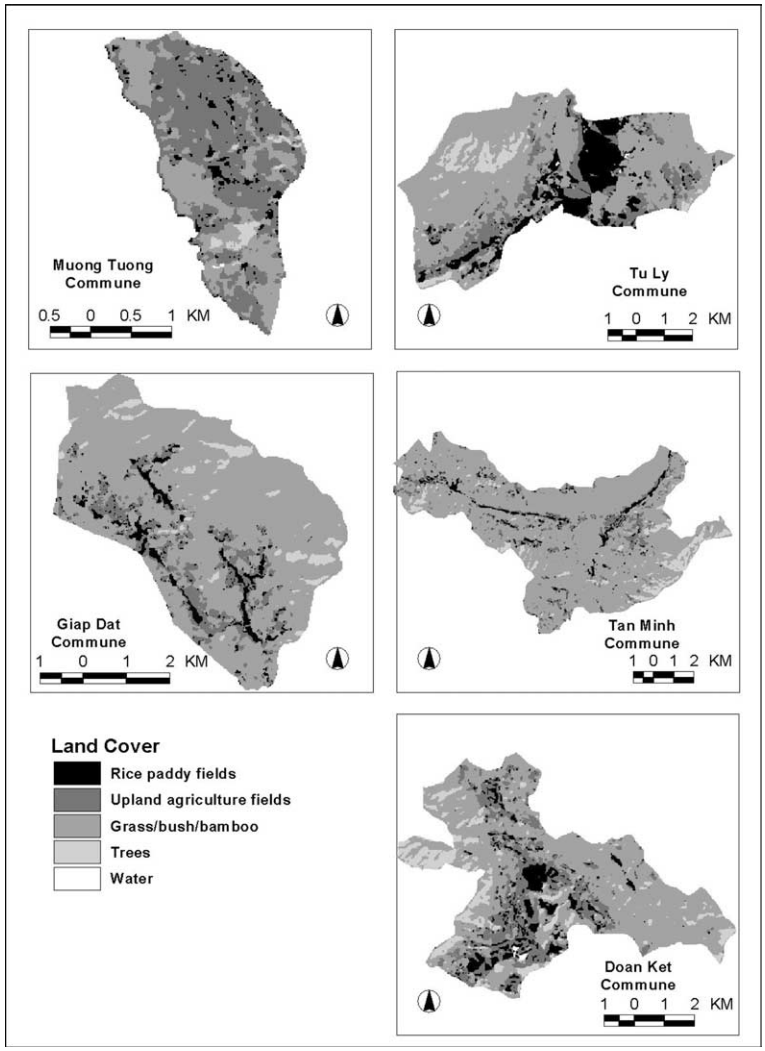

Fig. 3. Examples of communes for visual analysis.

in the five districts studied were classified. After this 21 communes were randomly chosen for field verification. Of these five were in Da Bac district and four each were chosen from the other districts. The number of communes chosen for checking was based on pragmatic reasons of time and finances available for carrying out the field checks. Data were collected at both commune and district level that corresponded to the 1999–2000 period.

At the commune level targeted interviews with local authorities and farmers were done to determine what type of farming systems are actually found in the area. Transects were walked and specific locations were visited to verify the accuracy with

which the general land cover types were classified. At each of these locations, pictures were taken and position locations recorded using GPS. This information was later used to verify the land cover classification.

At the district level local authorities were visited and an overview of the district's farming systems was obtained. Specific information obtained includes: annual reports for agricultural activities in each commune, the area and production of rice paddy and rice swidden, maize and other crops, and the area where non-timber forest products are collected. Due to time constraints in the field only 19 of 21 communes were visited.

4. Results

The results of the field check show that there was an 80% agreement between the communes' classified general farming system types and the actual general farming system types (Table 4). Where there was disagreement between the classification's result and the actual, the rules were re-examined and revised as necessary. The communes for each district were reclassified using the new rules and a final map of each district's communes' general farming system types was made.

The main results of the study are thus a set of rules based on landscape metrics that allow for the mapping of general farming system types by commune for these parts of the NMR (Table 5) and five district maps showing the general farming system types by commune (Fig. 4). As noted, the rules based on three landscape metrics and on a visual pattern analysis of all the land cover by commune initially produced an average of 80% agreement between the classified farming systems and the actual farming systems found in each commune. The results of field checking the initial map were used to revise the rules so better final mapping accuracy could be reached and a 100% agreement for the 19 communes attained. Although it is recognized that a separate field check of the revised map is desirable, this was not accomplished.

The five district maps illustrate that out of the 126 communes found in these districts, only 12 have "pure" farming systems present in them, and of these only two are pure rotational swidden farming systems. In the other 114 communes, the farming systems are made up of a mixture of upland farming and lowland farming areas, most likely rice paddy (Table 6). This result illustrates over a wide area the important role that rice paddy fields play in the NMR farming systems, an observation also reported, albeit on a case-by-case basis, by other authors (Pandy and van Minh, 1998; Castella and Erout, 2002).

The results also indicate that in 1999/2000 only 22 of the 126 communes have farming systems that could be labeled as "extensive" swiddening systems. In this case, the label "extensive" includes both pure rotational swidden systems and composite swidden systems. The other 104 communes all have some form of "intensive," or permanent, farming system in them.

Based on the rules developed, a farming system change over time analysis was done for Thanh Son district. The analysis shows that in 1992 37 communes had some form of swiddening in them, and of these 17 had composite swiddening systems.

Table 4
Predicted farming system and actual farming system types for communes checked

District/Commune	Predicted	Actual	Agreement
District: Da Bac			
Dong Nghe	• CSA/S[a]	• CSA/S	100
Suoi Nanh	• CSA/S	• PUA[b] • CSA/S	50
Muong Chieng	• CSA/S	• CSA/S	100
Tan Pheo	• CSA/S	• CSA/S	100
Cao Son	• PRP[c] and • PUA	• PRP and • PUA • CSA/S	66
District: Bac Yen			
Chim Van	• PRP and • PUA • CSA/S	• PRP and • PUA • CSA/S	100
Phieng Ban	• PUA	• PUA	100
Ta Xua	• PRP and • PUA • CSA/S	• CSA/S	33
Bac Nga	• PRP and • PUA	• PRP and • PUA	100
District: Sapa			
Ho	• PRP and • PUA	• PRP and • PUA	100
Ta Van	• PRP and • PUA	• PRP and • PUA	100
Su Pan	• PRP and • PUA	• PRP and • PUA	100
Ban Khoang	Not able to visit – time constraint		
District: Thanh Son			
Thu Ngac	• PRP and • PUA • CSA/S	• PRP and • PUA	66
Thu Cuc	• PRP and • PUA • CSA/S	• PRP and • PUA	66
Cu Dong	• PRP	• PRP	100
Kim Thuong	Not able to visit – time constraint		
District: Van Chan			
Thuong Bang La	• PRP	• PRP and • PUA	50
Nam Bung	• PRP and • PUA	• PRP and • PUA	100
Nam Lanh	• RSA[d]	• PRP and • PUA	0
Nghia Loi	• PRP	• PRP	100
Average agreement between predicted and actual			80

[a] CSA/S: Composite swidden or composite swidden and other swidden.
[b] PUA: Permanent upland agriculture.
[c] PRP: Permanent rice paddy.

Only two communes' farming systems in 1992 did not include swiddening. This is compared to 2000 when 13 communes had farming systems that included no swiddening (Fig. 5).

Table 5
Rules for classifying general farming system type by commune

General village level farming system type	% of Landscape under ag.	Ratio of upland ag. to rice paddy	NLSI upland	NLSI rice paddy	Landscape pattern guidelines for visual interpretation[a]
Pure systems					
Rotational swidden system (RSA)	Less than 25%	Greater than 10:1	>0.27	>0.40	Little rice paddy (very scattered); upland ag. (0.3 ha to 10 ha) patches; regrowth and trees intermixed with patches of upland ag. and paddy.
Permanent rice paddy system (PRP)	Greater than or equal to 40%	Less than 1:7	Not important	<0.20	Little upland ag.; rice paddy (large areas); other land cover (large continuous areas)
Permanent upland agriculture system (PUA)	Greater than or equal to 40%	Greater than (±)8:1	<0.20	Not important	Little rice paddy; permanent upland ag. (large areas); other land cover (large continuous areas)
Mixed systems					
Systems with PRP and PUA	Greater than 25%	Roughly equal; can be more 7:1 or 1:7	<0.20 (can be >0.20, determined by visual analysis)	<0.20	Rice paddy and upland ag. (large and aggregated); other types of land cover (aggregated). Few to no scattered upland ag. fields.
Systems with PUA and RSA	Between 25% and 50%	Greater than 10:1	Between (±)0.20 and 0.28	N/A	Large continuous upland ag. in parts of commune; patches of upland ag. interspersed with other land cover in other parts of commune. Little if any rice paddy.

Systems with PUA, PRP and RSA (can be CSA)	Between 25% and (±)40%	Usually roughly equal; can be more 3:1 or 1:3	Between 0.20 and 0.28 (can be >0.28; determined by visual analysis)	>0.28	Large continuous upland ag. found in parts of commune; large continuous rice paddy found in parts of commune; patches of upland ag. (swidden) interspersed with other land cover. (If in close proximity (500 m) of small and/or medium size paddy then can be CSA).
CSA or mixed CSA RSA in the same commune	Less than 25%	Greater than 1.5:1 (can be 1:1 or have more paddy than swidden; refer to visual analysis)	>0.27	>0.27	Patches of upland ag. 0.3 to 10 ha (swidden) interspersed with other land cover (regrowth and trees); in close proximity (500 m) of small to medium size paddy. If rotational swidden fields not in close proximity to rice paddy, can be areas of "only" RSA.

[a] When pattern and metrics do not agree, more weight is given to the visual interpretation of pattern.

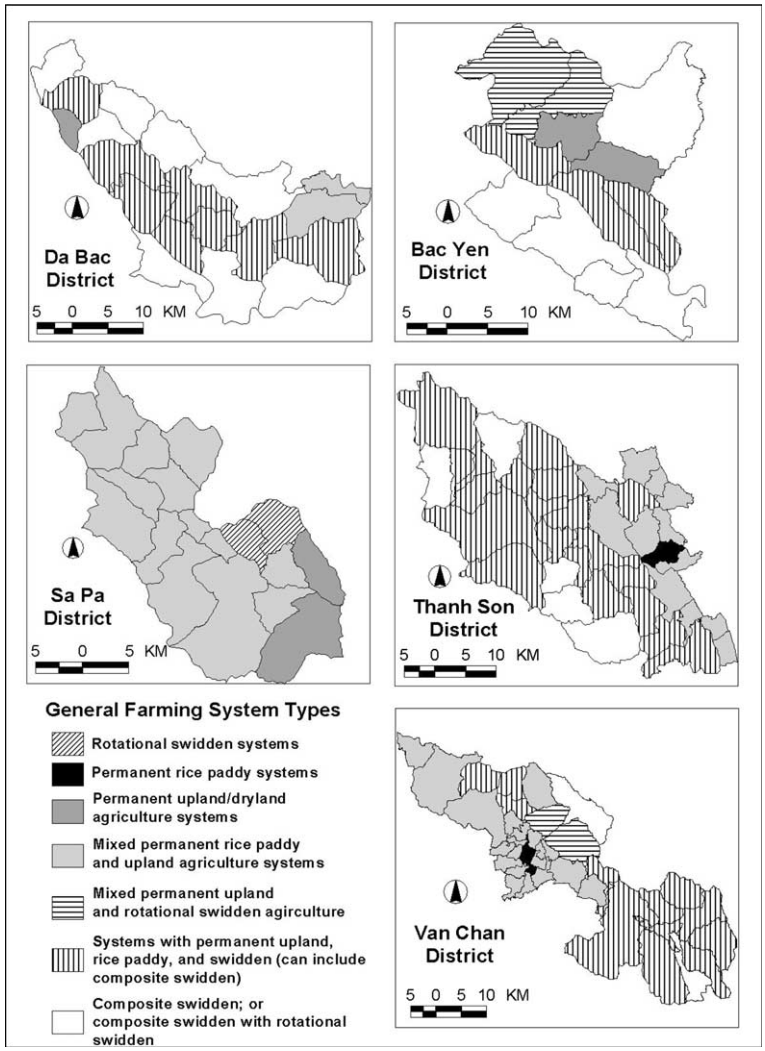

Fig. 4. District maps showing general farming system types by commune.

A commune-by-commune comparison of the general farming system types for Thanh Son in 1992 and 2000 reveal that in general, farming systems changed within the communes from systems characterized by extensive forms of agriculture, e.g. swiddening, to systems characterized by intensive forms of agriculture, e.g. permanent upland and rice paddy fields. Specifically, 11 communes that had "mixed" permanent upland, permanent rice paddy, and rotational swidden systems became communes with mixed permanent upland and rice paddy systems, and 12 communes that had composite swidden systems became communes with "mixed" permanent upland, permanent rice paddy, and rotational swidden systems (Table 7). In this

Table 6
Distribution of farming system type in five study districts

General farming system type	Number of communes	Percent of total
"Pure" General farming system type		
Rotational swidden agriculture	2	2
Permanent rice paddy agriculture	5	4
Permanent upland agriculture	5	4
"Mixed" General farming system type		
Mixed permanent rice paddy and upland agriculture	45	37
Mixed permanent upland agriculture and rotational swidden agriculture	4	3
Systems with permanent upland, rice paddy, and swidden agriculture (can include composite swidden)	44	35
Composite swidden agriculture; or composite swidden with rotational swidden agriculture	19	15

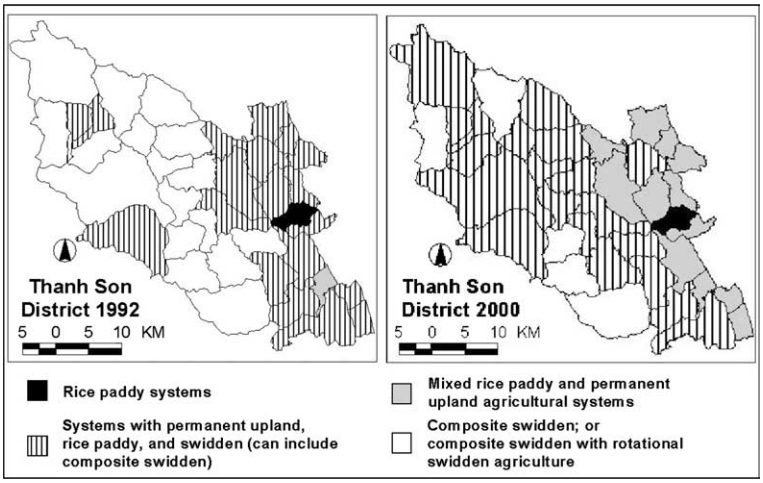

Fig. 5. General farming system types in Thanh Son District, Phu Tho Province in 1992 and 2000.

Table 7
General farming system types in Thanh Son district's communes 1992–2000

Farming system type	1992 (communes)	2000 (communes)
Pure: permanent rice paddy agriculture	1	1
Mixed: permanent upland and permanent rice paddy agriculture	1	12
Mixed: permanent upland, permanent rice paddy, and rotational swidden (can include CSA)	19	20
Mixed: Composite swidden agriculture	17	5

district, each commune has had an increase in the area that is under agricultural use. Both the trend in the changes of the general farming systems in Thanh Son district and the large number of communes in the other districts in 1999/2000 that have permanent farming systems, correspond with other researchers' observations that agricultural intensification is taking place in the NMR (Tachibana et al., 2001; Wezel, 2000).

5. Discussion

The results show that a GIS model using spatial data and calibrated with knowledge of the farming systems can be used to map the distribution of the general farming system types detailed in this paper at the commune level. One reason the model works is that it makes use of the spatial land cover patterns associated with the different general farming system types. Because the landscape as a whole is looked at for each commune the difficulty noted by Padoch and Coffey (2003), that the different land covers resulting from the swidden/fallow cycle are relegated to the residual category in land cover classifications, does not happen here. Rather, it is the relative complexity of the different agriculture system's land cover and the proximity of each of the land cover types to each other that is the basis for classifying a commune as having a specific farming system type.

The permanent farming systems are identified by their land cover being less complex and more homogeneous over a large area. In communes having permanent agricultural farming systems, land cover associated with permanent agriculture, e.g. rice paddy and bare land, cover large continuous areas. The land cover that belongs in the categories of bush, bamboo, or tree cover, if found at all, are also aggregated into homogeneous patches and are relegated to the edge of the agriculture related land cover areas. In communes with rotational swidden and/or composite swidden areas, the land cover patterns associated with these types of farming systems are found. If the rotational or composite swidden is also found in a commune with permanent farming system types, the two land cover patterns are visually distinct in different parts of the commune.

Despite the favourable results of this study there is at least one weakness that should be noted. Even while obtaining 80% accuracy in the initial classification process, it was noted during fieldwork that it is difficult to account for terraced rice paddies, a situation exemplified by the Sa Pa District. While the general farming system types distribution by commune appear to be correct, it is recognized that the incidence of terraced rice paddy is most likely not correctly reflected in the land cover analysis that is part of the GIS model for Sa Pa. This shows that the methods used here and the GIS model are sensitive to the size of terraced rice paddies. If the terraces are too small they will be misclassified and mapped as upland agriculture fields. The misclassification was not serious with regards to Sa Pa, because of the generalization of the farming system classification to the commune level, a level at which both permanent upland and rice paddy agriculture is found. However, if

the classification were done at a more detailed level than the commune the errors would become evident.

The finding that most of the communes in the districts studied have more than one of the general farming system types reflects the diversity of the geographical and cultural landscape of the NMR and the varying livelihood strategies that farmers follow. While these observations have been noted in other local case studies (Donovan et al., 1997; Jamieson et al., 1998; Cuc and Rambo, 2001; Castella et al., 2002a,c), the current results support the contention that these observations are also valid spatially, across large areas of the NMR.

A limitation to the study was that due to shortness of time and lack of data, specifically appropriate satellite imagery, only one district had a change over time analysis done for it. However, for this one district there is evidence of a trend towards the adoption of permanent agricultural systems and away from swidden or composite swiddening systems. Results from interviews conducted during the field check confirm this. Farmers note in a number of interviews across all five of the districts, that in the past they practiced swidden or composite swiddening, but today they practice some form of permanent agriculture. The upland crops that are reported to be favoured in these systems, such as maize and cassava, and the plantation crops, such as tea, are oriented towards the market. Although it was not an objective of the present study, this finding does indicate one possible explanation for the changing of the general farming system types within the communes. As the communes become more connected to the external world, the market can act as a "pulling" function, providing the farmers with incentives to grow crops for the market, many of which are well suited for permanent agricultural systems. In this way, farmers are further encouraged to expand the practice of permanent forms of agriculture. Use of more accurate road data and including data on market location could help one test this hypothesis. Including these data layers would be a "next-step" in moving the GIS model from one focused on identifying where general farming system types are found by commune to explaining why the general farming systems types are found where they are.

The observed trend in farming systems changing from extensive, rotational swidden systems, to more permanent, intensive systems may also be indicative of other pressures. Although explaining why these changes are taking place was not a focus of this work, it is worth noting that population growth is likely playing a role in these changes. As others point out, there has been an increase in population in the NMR in the recent past. Population increase can act as a "pushing" function on the farming systems: increasing pressure on land causes a decrease in fallow length (Fox et al., 2000; Cuc and Rambo, 2001). This influences the move from farming systems that include some form of swidden to farming systems that are 100% based on permanent agriculture, or at least have permanent agriculture as a significant part of a commune's general farming system type (Tachibana et al., 2001).

The identified trend towards more permanent agricultural practices could also suggest that the land allocation policies of the Vietnamese government are having an impact on people's choices of farming practices. One reason that a number of interviewees gave for the movement from swiddening towards systems based on

permanent agriculture is that the land allocation policy promulgated in 1994 and applied in the NMR from the late 1990s has discouraged farmers from continuing swiddening and encouraged them to cultivate the same upland area year after year (Gomiero et al., 2000). Researching the effects of land allocation was not an objective of the study, but evidence for this change of behaviour was uncovered during field work interviews with farmers in the communes studied.

Finally, some may suggest that data on ethnicity could be added to help explain why the farming systems are found where they are. Kunstadter and Chapman (1978) note that in northern Thailand different ethnic groups are closely related to specific agricultural practices and the same is thought to be true for the ethnic minority groups in the NMR. Following this, integrating ethnic minority data could add another variable for predicting a commune's farming system. The difficulty in currently using these data is that ethnicities can be mixed within a commune, so connecting ethnicity to farming system practiced would be complicated when the commune's farming system type is mixed and there is more than one ethnicity living there. Further, some studies have shown that there is a breakdown in the link between ethnicity and farming system type taking place in the NMR (Castella et al., 2002b). Given these complications and uncertainties about the role of ethnicity and farming practices, including ethnicity could actually weaken the GIS model and decrease the accuracy of the resulting map.

6. Conclusions and perspectives

The successful validation of the methodology presented in this paper suggests that an expansion of the GIS model could provide a method for accurately mapping the extent of different general farming system types across the whole of the NMR. Potentially the method could be augmented with other available data and expanded to map the extent of general farming system types across the whole of the montane Southeast Asia region. Expanding the GIS model on a regional basis would provide researchers who focus on the question of what is the extent of swiddening with a more accurate picture than that gleaned from case studies of how the farming system is currently distributed across the region, as well as the extent of other general farming systems in the region.

It needs to be noted that other data could help to refine the results of the GIS model and transform it from a model aimed at describing a situation so it can be mapped, to explaining why the general farming system types are found where they are found and to help explain why agricultural intensification is taking place. Currently the GIS model only makes use of the authors' knowledge regarding the relationship between the farming practices found in the commune and a commune's landscape and geographical data that are available to HAU in digital form. The authors' knowledge has been gained through years of farming systems research and land use/land cover change research in the NMR of Vietnam. The digital data have been collected over the life of various projects that have been carried out by researchers from HAU. Adding other layers of data, as noted in

Section 5, to the GIS model could help to both refine its accuracy and add explanatory power to it.

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References

Castella, J.C., Erout, A., 2002. Montane paddy rice: the cornerstone of agricultural production systems in Bac Kan Province, Viet Nam. In: Castella, J.C., Quang, D.D. (Eds.), Doi Moi in the Mountains. The Agricultural Publishing House, Hanoi, Vietnam, pp. 175–195.

Castella, J.C., Quang, D.D., Long, T.D., Doanh, L.Q., 2002a. Scaling up local diagnostic studies to understand development issues in a heterogeneous mountain environment: An introduction to the SAM Program. In: Castella, J.C., Quang, D.D. (Eds.), Doi Moi in the Mountains. The Agricultural Publishing House, Hanoi, Vietnam, pp. 1–18.

Castella, J.C., Tran, Q.H., Husson, O., Vu, H.N., Dang, D.Q., 2002b. The declining role of ethnicity in farm household differentiation: a case study from Ngoc Phai Commune, Cho Don District, Bac Kan Province, Viet Nam. In: Castella, J.C., Quang, D.D. (Eds.), Doi Moi in the Mountains. The Agricultural Publishing House, Hanoi, Vietnam, pp. 47–71.

Castella, J.C., Tronche, N.R., Nguyen, V., 2002c. Landscape changes in Cho Don District during the doi moi era (1990–2000) and their implications for sustainable natural resource management in Viet Nam's mountainous provinces. In: Castella, J.C., Quang, D.D. (Eds.), Doi Moi in the Mountains. The Agricultural Publishing House, Hanoi, Vietnam, pp. 149–173.

Cuc, L.T., Gillogly, K., Rambo, A.T., 1990. Agroecosystems of the Midlands of northern Vietnam. Program on Environment Occasional Paper No. 12. Honolulu, East-West Center.

Cuc, L.T., Rambo, A.T., 2001. Some key findings of the CRES Project on monitoring development trends in Vietnam's northern mountain region. In: Cuc, L.T., Rambo, A.T. (Eds.), Bright Peaks, Dark Valleys: A Comparative Analysis of Environmental and Social Conditions and Development Trends in Five Communities in Vietnams' Northern Mountain Region. The National Political Publishing House, Hanoi, Vietnam, pp. 1–30.

Dang Nghiem, Van., 1991. La culture sure brulis et le nomadisme. Etudes Vietnamiennes 1 (99), 16–28.

De Koninck, R., 1999. Deforestation in Vietnam. International Development Research Center, Ottawa, Canada.

Donovan, D., Rambo, A.T., Fox, J., Cuc, L.T., Vien, T.D. (Eds.), 1997. Development Trends in Vietnam's Northern Mountain Region, vols. 1 and 2. Hanoi National Political Publishing House.

Fatoux, C., Castella, J.C., Zeiss, M., Manh, P.H., 2002. From rice cultivator to agroforester within a decade: The impact of Doi Moi on agricultural diversification in a mountainous commune of Cho Moi

District, Bac Kan Province, Viet Nam. In: Castella, J.C., Quang, D.D. (Eds.), Doi Moi in the Mountains. The Agricultural Publishing House, Hanoi, Vietnam, pp. 73–97.

Fox, J., Truong, D.M., Rambo, A.T., Tuyen, N.P., Cuc, L.T., Leisz, S., 2000. Shifting cultivation: a new old paradigm for managing tropical forests. Bio-Science 50, 521–528.

Gillogly, K.T., Charoenwatana, T., Fahrney, K., Panya, O., Namwongs, S., Rambo, A.T., Rerkasem, K., Smutkupt, S.S., 1990. Two upland agroecosystems in Luang Prabang province, Lao PDR: A preliminary analysis: Report on the SUAN-Lao seminar on rural resources analysis in Vientiane and Luang Prabang, Lao PDR from 4–14 December, 1989. The SUAN Secretariat Farming Systems Research Project. Khon Kaen University, Khon Kaen, Thailand.

Gomiero, T., Pettenella, D., Giang, P.T., Maurizio, P., 2000. Vietnamese uplands: environmental and socio-economic perspective of forest land allocation and deforestation process. Environment, Development and Sustainability 2, 119–142.

Hung, D.T., Trung, T.C., Cuc, L.T., 2001. Agroecology. In: Cuc, L.T., Rambo, A.T. (Eds.), Bright Peaks, Dark Valleys: A Comparative Analysis of Environmental and Social Conditions and Development Trends in Five Communities in Vietnams' Northern Mountain Region. The National Political Publishing House, Hanoi, Vietnam, pp. 51–83.

Jamieson, N.L., Cuc, L.T., Rambo, A.T., 1998. The Development Crisis in Vietnam's Mountains. East-West Center Special Reports, Number 6. East-West Center, Honolulu, Hawaii.

Kyuma, K., Pairintra, C., 1983. Shifting cultivation, an Experiment at Nam Phrom, Northeast Thailand, and Its Implications for Upland Farming in the Monsoon Tropics. Tokyo, Japan.

Kunstadter, P., 1978. Subsistence agricultural economies of Lua' and Karen hill farmers, Mae Sariang district, northwestern Thailand. In: Kunstadter, P., Chapman, E.C., Sabhasri, S. (Eds.), Farmers in the Forest. The University Press of Hawaii, Honolulu, pp. 74–133.

Kunstadter, P., Chapman, E.C., 1978. Problems of shifting Cultivation and Economic Development in northern Thailand. In: Kunstadter, P., Chapman, E.C., Sabhasri, S. (Eds.), Farmers in the Forest. The University Press of Hawaii, Honolulu, pp. 3–23.

Laney, R.M., 2004. A process-led approach to modeling land change in agricultural landscapes: a case study from Madagascar. Agriculture, Ecosystems, and Environment 101 (2004), 135–153.

Leisz, S., Dao, M.T., Le, T.C., Le, T.H., 2001. Land-cover and land use. In: Cuc, L.T., Rambo, A.T. (Eds.), Bright Peaks, Dark Valleys: A Comparative Analysis of Environmental and Social Conditions and Development Trends in Five Communities in Vietnams' Northern Mountain Region. The National Political Publishing House, Hanoi, Vietnam, pp. 84–122.

McGarigal, K., Marks, B.J., 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. Gen. Tech. Report PNW-GTR-351, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Morrison, E., Dubois, O., 1998. Sustainable livelihoods in upland Vietnam: land allocation and beyondForestry and Land Use Series, 14. International Institute for Environment and Development (IIED), London, England, pp. 64.

Myers, N., 1993. Tropical forests: the main deforestation fronts. Environmental Conservation 20, 9–16.

Padoch, C., Coffey, K., 2003. Monitoring the demise of swidden in Southeast Asia: local realities and regional ambiguities. In: Mertz, O., Wadley, R., Christensen, A.E., (Eds.), Local Land Use Strategies in a Globalizing World: Shaping Sustainable Social and Natural Environments. Proceedings of the International Conference August 21–23, 2003, vol. 1. DUCED SLUSE, Institute of Geography, University of Copenhagen, Copenhagen, pp. 103–124.

Pandy, S., van Minh, D., 1998. A socio-economic analysis of rice production systems in the uplands of northern Vietnam. Agriculture, Ecosystems and Environment 70 (2–3), 249–258.

Phong, T.A., 1993. Contribution to building up agriculture and sustainable development in our country. Scientific Activity Review No. 6. Ministry of science, Technology and Environment, Hanoi (in Vietnamese).

Prill-Brett, J., 1986. The Bontok: Traditional wet rice and swidden cultivators of the Philippines. In: Marten, G.G. (Ed.), Traditional Agriculture in Southeast Asia. Westview Press, East-West-Center, Honolulu, pp. 54–84.

Rambo, A.T., 1998. The composite swiddenning agroecosystem of the Tay Ethnic Minority of the Northwestern Mountains of Vietnam. In: Patanothai, A. (Ed.), Land Degradation and Agricultural Sustainability: Case Studies from Southeast and East Asia. Regional Secretariat The Southeast Asian Universities Agroecosystem Network (SUAN), Khon Kaen University, Khon Kaen, Thailand, pp. 43–64.

Riswan, R., Hartanti, L., 1996. Human impacts on tropical forest dynamics. Vegetatio 121, 41–52.

Roche, Y., Michaud, J., 2000. Mapping ethnic groups in Lao Cai Province, Vietnam. Asia Pacific Viewpoint 41 (1), 101–110.

Tachibana, T., Nguyen, T.M., Otsuka, K., 2001. Agricultural intensification versus extensification: A case study of deforestation in the northern-hill region of Vietnam. Journal of Environmental Economics and Management 41 (1), 44–69.

Tran, D., 2003. The Farm Economy in Vietnam. The Gioi Publishers, Hanoi.

Tran, D.V., 1998. Soil erosion and nutrient balance in swidden fields of the composite swiddening agroecosystem in the Northwestern mountains of Vietnam. In: Patanothai, A. (Ed.), Land Degradation and Agricultural Sustainability: Case Studies from Southeast and East Asia. Regional Secretariat The Southeast Asian Universities Agroecosystem Network (SUAN), Khon Kaen University, Khon Kaen, Thailand, pp. 65–84.

Tran, D.V., Pham, C.T., 1996. Agriculture on Sloping Lands: Challenges and Potentials (A Selection of Research Done on the Period of 1991–1996 by Hanoi Agricultural University). Agricultural Publishing House, Hanoi (in Vietnamese).

Walker, R., 2003. Mapping Process to Pattern in the Landscape Change of the Amazonian Frontier. Annals of the Assoc. of Am. Geog. 93 (2), 376–398.

Wezel, A., 2000. Weed vegetation and land use of upland maize fields in north-west Vietnam. GeoJournal 50, 349–357.