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An Assessment of Trends in the Extent of Swidden in Southeast Asia

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Abstract Swidden systems consisting of temporarily cultivated land and associated fallows often do not appear on land use maps or in statistical records. This is partly due to the fact that swidden is a diverse and dynamic land use system that is difficult to map and partly because of the practice of grouping land covers associated with swidden systems into land use or land cover categories that are not self-evidently linked to swiddening. Additionally, in many parts of Southeast Asia swidden systems have changed or are in the process of changing into other land use systems. This paper assesses the extent of swidden on the basis of regional and national sources for nine countries, and determines the pattern of changes of swidden on the basis of 151 cases culled from 67 articles. Findings include (1) a majority of the cases document swidden being replaced by other forms of agriculture or by other livelihood systems; (2) in cases where swiddening is still practiced, fallow lengths are usually, but not always, shorter; and (3)

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shortened fallow length does not necessarily indicate a trend away from swidden since it is observed that short fallow swidden is sometimes maintained along with other more intensive farming practices and not completely abandoned. The paper concludes that there is a surprising lack of conclusive data on the extent of swidden in Southeast Asia. In order to remedy this, methods are reviewed that may lead to more precise future assessments.

Keywords Swidden cultivation · Land use and land cover change · Fallow · Southeast Asia

Introduction

Swidden cultivation, while found throughout the uplands of Southeast Asia, often does not show up on land use maps or in statistical records (Padoch *et al.* 2007). While cleared fields in a swidden system may be identified on a map as agricultural land, the land cover associated with the fallow phase, e.g. herbs, grasses, bush, bamboo and different phases of tree cover, is often not recorded on land use/cover, cadastral, and land-use planning maps of the region as belonging to the swidden cultivation complex. A factor complicating the identification of these land cover types as being associated with swidden is that they are transitional land covers, changing from year-to-year as the vegetation matures and/or is replaced by other vegetation types in the course of succession. Complexity and dynamics within the land cover create difficulties in accurately delineating and mapping even when digital image processing or visual interpretation techniques are used in conjunction with satellite imagery or air photos. Land use/cover classification exercises are further complicated by the fact that swidden is often not the sole land use in a region, but occurs embedded in a matrix of other land uses.

Land covers associated with the fallow phase of a swidden field are often grouped into 'unclassified', 'barren', 'wasteland' and 'cropping mosaic' categories, or into vegetation categories such as 'wood- and shrub-lands', and 'forest regrowth' along with land covers that are not associated with swidden. Labelling land as 'shifting cultivation' is often meant to indicate the potential for developing other forms of agriculture or forestry on an area or to indicate a degraded forest area.

For a definition of swidden cultivation, please see the introduction to this issue (Mertz *et al.* 2009). Our understanding of swidden in Southeast Asia is that it is synonymous with shifting cultivation and includes both the cultivated fields—the 'swiddens'—and the fallow lands. This paper has three goals. The first is to review the different land use and land cover classifications used on national and regional scale maps and in remote sensing analyses of the region in order to identify how swidden is dealt with (or not dealt with) in these classifications. The second is to provide an overview of the evidence that can be culled from these various classifications and surveys for identifying the extent of swiddening within the region. To accomplish this goal, time series information will be examined with the express intent of identifying trends in how the extent of swidden is changing in the region. The third is to examine prospective methods for identifying and quantifying swidden areas.

The paper is based on data derived from the literature, archives, government reports and various completed and on-going analyses of land use/cover in the region. A broader intent of the paper is to provide an assessment of the regional state of the art that may assist in identifying research gaps and needs in Southeast Asia and which may be applied to other regions of the world where similar situations exist. We believe that precise or at least realistic estimates of the extent and changes of land area under swidden, which is still an important land use in Southeast Asia, are a prerequisite for reducing poverty, improving livelihoods, and maintaining ecosystem services in the region.

Swidden in Southeast Asia—Regional and Country Assessments of Swidden Systems: Issues and Problems

Swidden is a diverse, complex, and dynamic land use that researchers have difficulty seeing and defining, much less measuring and quantifying. Because of this complexity or "illegibility," as well as other characteristics of the practice and its practitioners, government agents often relegate swidden lands to categories such as "wasteland/abandoned/unused" or "residual/miscellaneous" in reports presented on provincial, national, and regional levels. The same situation is found in regional land cover analysis projects, such as the FAO's decadal forest inventory assessment, the European Space Agency's TREES Project, and NASA's Pathfinder Project. Each of these projects regularly collects remote sensing and other data that is used to interpret land cover for Southeast Asia. However, Fox (2000) notes that, in many of these large-scale land-use classifications for Southeast Asia, from one-third to one-half of "non-forested" land may be placed into "unclassified" or "other" categories. Much of this land may represent swidden or swidden-in-transition areas, but because the data is not interpreted with the goal of identifying swidden areas, and, indeed, the identification of swidden areas may not be possible given the above noted complexity and the remote sensing techniques that these projects are using (Leisz and Rasmussen in press), the location of swidden areas has not been extracted from the remote sensing data available.

Quantifying land use change and mapping swidden cultivation in Southeast Asia have been tried before. A map of the distribution of swidden in the Asia-Pacific region, published in the Conservation Atlas of Tropical Forests: Asia and Pacific (Collins *et al.* 1991, p. 32), and based on the regional analysis of swidden in Southeast Asia by Spencer (1966), shows that swidden is the dominant, though not the exclusive land use on nearly 50% of the land area of Southeast Asia. A later study on land use changes in Southeast Asia between 1880 and 1980 focused on temporary crops, permanent crops, forest/woodland and "interrupted" forest and thus gives few indications on the changes in the extent or practice of swidden, which are concealed in the overlap between these categories (Richards and Flint 1994). In the same book Uhlig *et al.* (1994) estimated that in the early 1980s approximately 5.5 to 6 million hectares were under swidden in Sarawak, Sabah and Thailand.

The most recent attempts at quantifying land cover change in SE-Asia were conducted by Heinimann (2006) in his analysis of land cover change patterns in the Lower Mekong Basin (LMB), and by Heinimann *et al.* (2007) in their assessment of the extent and dynamics of secondary forests in the LMB. These studies rely on analysis of the MRC/GTZ forest cover data sets for 1993/1997 for the LMB (MRC/GTZ 1998). With respect to the assessment of secondary forests, the problem in using this dataset is that secondary forests are not delineated as a separate aggregated forest class. For the purpose of Heinimann's (2006) and Heinimann *et al.*'s (2007) studies the categories "medium to low cover density" (FMD), and "forest mosaics" (FM) are considered to be proxies for secondary forest. They may be considered to be proxies for swidden fallow as well. This assumption is, however, burdened with a certain margin of error. First, not all secondary forests, even those in the uplands, are fallow forests. Second, some dry and deciduous forests in the foothills and lowlands, which are not necessarily secondary in nature, can be quite open and may thus fall under the category "medium to low cover density", and, conversely, some secondary forests can be quite dense. A similar approach is followed by Mittelman (2001), who reviews various data sets for changes in secondary forest cover in Cambodia, Laos, Thailand and Vietnam between 1993 and 1997. The approach of Heinimann (2006) and Heinimann *et al.* (2007) differ from that of Mittelman in that their analysis of land cover and related change trajectories is not limited to secondary forests, but considers the entire spectrum of land cover classes and change trajectories. However, no attempt was made to assess the extent and dynamics of swidden mainly because accurately differentiating wood and shrubland from a land cover mosaic of cropping and other land covers is a very laborious task when intermediate resolution Landsat TM imagery is used. An additional factor rendering the differentiation difficult is the tremendous seasonal variation of vegetation density, i.e. the volume of vegetation in green foliage, in non-forested areas under the monsoonal conditions of Southeast Asia. As a result, land cover transformation between these land cover classes, even though characteristic of swidden systems, cannot be used as a proxy for swidden activities based on the respective regional land cover datasets.

In the absence of a satisfactory regional assessment an attempt is made in the following paragraphs and in Table 1, to summarize the information regarding the extent of swidden on a country by country basis.

In Thailand, swidden cultivation is practiced mainly in the northern uplands close to the border with Laos and Myanmar. Rotational swidden cultivation can still be found in a corridor along the Thailand–Myanmar border from Mae Hong Son in the north to Tak in the south (Rerkasem and Rerkasem 1994). Estimates of the swidden area in Thailand in the mid-1980s were about 1 million ha (Uhlig *et al.* 1994), but later data are not available. The Forestry Statistics of Thailand use a classification system that is based on floristic composition and phenology differentiating types such as "tropical evergreen forest" or "mixed deciduous forest" or "scrub forests", which cannot be linked to swiddening. Swidden fallow forests, depending on their condition and location could fall under each one of these categories.

The proportional extent of swidden is likely to be greater in Laos than in any other country in Southeast Asia. Two assessments are available for the early 1990s. Based on the assumptions that 300,000 families or 1.8 million people (equivalent to 40%) of the population are engaged in swiddening, and that each family plants about 1.5 ha per year, Hansen (1998) estimated that 450,000 ha would be used annually for swiddening, and that the total area in the swiddening cycle could be 2–2.5 million ha, equal to about 10% of the area of Laos. Chazee (1994), based on a comparison of aerial photographs from 1981/1982 and 1988/1989, estimated that 4,864,000 ha were used in shifting cultivation in 1989 (equal to 20.5% of the area of Laos), with a decline of the average fallow period from 12 years in 1981/1982 to 8 years in 1989. Messerli *et al.* (2009) applied a recently developed landscape mosaic approach, which analyzes patterns in the spatial coexistence of land cover types, to the territory of the Lao PDR, and identified the extent of 'swidden cultivation landscapes' at approximately 6,500,000 ha or 28.2% of the area of Laos.

In Cambodia swidden is mainly found in Ratanakiri province in the northeast of the country. The Atlas of Cambodia: National Environment and Poverty Maps (SWC 2006) shows swidden areas on a map of land use (p. 11) and on a map of terrestrial vegetation and land use patterns

Table 1 Regional and national estimates of land under swidden in Southeast Asia

Country	Estimate	Source of data	Reference
Thailand	1.0 million hectares	Based on FAO/UNEP study, data from early 1980s	Uhlig *et al.* (1994)
Laos	2–2.5 million hectares	Assessment based on census data	Hansen (1998)
	4.8 million hectares	1981/1982–1988/1989 aerial photographs of the Forest Inventory and Management Office	Chazee (1994)
	6.5 million hectares	2002 SPOT satellite images	Messerli *et al.* (2009)
Cambodia	349,000 ha	JICA dataset 2002	SCW (2006)
Vietnam	1 fifth of total land area	General Department of Land Administration, 2001	Nicolic *et al.* (2008)
Yunnan	No estimates		
Myanmar	2.43 million hectares	Estimate based on forest inventory data from the early 1990s	Ministry of Forestry (1995)
	5.32 million hectares	Analysis of Satellite imagery 1995–2000	Forest Department Myanmar 2000 (cited in Hlaing 2004)
	10. 18 million hectares	Estimate based on forest inventory data from the early 2000s	Forest Department Myanmar 2003 (cited in Htun 2007)
	0.29 million hectares	Unpublished data circulated within the Department	Planning and Statistics Division, Forest Department Myanmar 2008
Malaysia	Sarawak, 2.3 million hectares and Sabah, 1.4 million hectares in 1980	Malaysian Department of Statistics	Uhlig *et al.* (1994)
Indonesia	Sumatra 3,428,600 ha, Kalimantan 5,457,400 ha, Sulawesi 526,900 ha, Maluku 216,400 ha, Papua 1,287,300 ha, NTB 63, 600 ha, NTT 323, 500 ha, E- & W-Timor 98,600 ha, Total (including Timor E and W) 11,402,300 ha	RePPProT data 1982	Weinstock (1990)
Philippines	No estimates		

(p 37). The land use map's legend indicates that the area under swidden cultivation is 349,000 ha. However, it is not clear whether this figure refers to area under swidden cultivation in 2002 only or whether it includes the associated fallow lands as well.

There has been no official attempt to categorize or map the extent of swidden in Vietnam. The land use and land cover maps do not have a category that officially includes swidden land. The land use and land cover maps drafted by the Forestry Department and published by the Cartography Publishing House in Hanoi divide forest land into five categories. Translated from Vietnamese they are: 'natural forest—special use', 'natural forest—protected forest', 'natural forest', 'artificial forest', and 'hill and mountain barren land' or 'hill and mountain land not yet in use' (also sometimes translated as 'wasteland' or 'unused land'). Researchers who work in the mountainous regions of Vietnam note that this last category appears to coincide with areas that are used for swidden (Leisz 2007). The barren land category covers about one fifth of the territory of Vietnam. In reality 98% of the land cover in barren areas consists of secondary formations such as grassland, grassland and bushes, scrubland with sparse trees, bamboo, and dense growth of small and medium size trees (dbh=5 to 15 cm; height up to 4 m), which can be associated with the fallow stages of the swiddening cycle (Nicolic *et al.* 2008).

In Myanmar, swidden agriculture is mainly practiced by ethnic minorities in the Karen, Shan, Kachin and Chin States of eastern and northern Myanmar. The available figures for Myanmar are extremely variable—even those provided by the same government agency—and thus exemplary of the problem faced by anyone trying to assess the extent of swidden on the basis of official records. Uhlig *et al.* (1994) estimated that 25.6 million ha were under combinations of swidden and permanent agriculture in Myanmar in the late 1980s. The Ministry of Forestry estimates that 1.5 to 2 million families practice swidden in an area of about 2.43 million ha (Ministry of Forestry 1995). Figures published by the Ministry of Forestry in

2003 indicate that swidden is practiced on an area of 10.18 million ha which is about 15% of the total area of the country (Htun 2007). The most recent statement from the same government agency reveals that the total area of "Ya" (the Myanmar term for "hill agriculture", which can be equated with swidden) within Reserved Forests and Protected Forests is only 0.29 million ha. This figure contrasts starkly with other available estimates mainly because it does not include the areas of hill agriculture outside protected forests. Hlaing (2004) cited the results published by the Forest Department in 2000 that are based on the analysis of satellite imagery (1995–2000), which estimates the total area under swidden (including fallow land) at 5.32 million ha.

Yunnan is considered to be a part of Southeast Asia mainly on account of Xishuangbanna Prefecture in southern Yunnan, which resembles neighboring regions of Laos, Myanmar and Thailand with respect to ethnic affiliation and dominant land use practices. Ethnic minorities such as Hani, Lahu and others have practiced swiddening extensively in the past. Swiddening, considered an unwanted land use, came under pressure due to successive policies of collectivization and economic development (Sturgeon 2005a, b) and has been largely replaced by other land uses, most notably by rubber plantations (Xu 2006). There is, however, no reliable estimate of the past or present extent of swidden.

The area under swidden in Peninsular Malaysia is negligible as most of the agricultural lands have been converted to permanent agriculture or plantations. Relatively large areas are still found in Sabah and Sarawak, but no published estimates of swidden areas are available since those of Uhlig *et al.* (1994) (see Table 1). This may be partly due to the fact that—especially in Sarawak—swidden lands are currently under pressure for conversion to other land uses such as oil palm plantations. Hence there is little interest from either the government or local people in publishing land information that may limit the possibilities in negotiations regarding which areas are classified as customary land or classified as state land (see Fox *et al.* 2009 and Ngidang 2002 for further discussion on land issues in Sarawak).

In Indonesia, where swiddening is mainly practiced in Kalimantan, Sumatra, Sulawesi and Papua, there is a similar pressure to convert swiddens to plantations. Weinstock (1990) gives the following assessment of the area under swidden cultivation in hectares based on REPPProt data, which he considers to be the best: Sumatra 3,428,600; Kalimantan 5,457,400; Sulawesi 526,900; Maluku 216,400; Irian Jaya (currently Papua and West Papua) 1,287,300; Nusa Tenggara Barat 63,600; Nusa Tenggara Timur 323,500; E- and W-Timor 98,600. The total area under swidden cultivation in Indonesia in the 1980s was estimated at 11,402,300 ha. Contemporary estimates have not been found.

In the Philippines, swidden is practiced in many parts of the country, especially in the uplands. There are, however, no reliable estimates of the extent of swidden areas.

Trends in Swidden System Changes: Analysis of 67 Articles Focusing on Swidden Systems in Southeast Asia

A review of 67 articles describing research on swidden across Southeast Asia (Table 2) reveals the following patterns of change in the systems: shorter average fallow lengths and the replacement of swidden systems with plantation agriculture or tree crops. It should be noted that the articles used varying methodologies and were not consistent in how many cases were examined in each article. A total of 151 cases across Southeast Asia are documented in the 67 articles, and in some articles different cases are documented that show contradicting changes to the systems discussed.

Changing Fallow Lengths

A total of 37 articles document 55 cases of active swidden systems across the region. Of these, 40 cases report that the average length of the fallow cycle has gotten shorter, while 15 report the fallow cycle remaining at a constant length. Overall more than half of these articles document decreases of fallow length within the system. The cases are spread across the region, with nine articles documenting cases of decreasing fallow lengths in Vietnam, seven in Laos, eight in Thailand, five in Malaysia, and four in China. Seven articles documented cases of decreasing fallow lengths in Indonesia, but five articles also documented cases of no change in the average fallow length of the system in other parts of Indonesia. There were no articles found documenting changes in the fallow lengths in Cambodia, Myanmar, and the Philippines. In Vietnam and Cambodia two articles discussed cases of the replacement of swidden systems with managed forest. These may be extreme cases where the fallow lands are being abandoned and replaced by forests.

Replacement of Swidden Systems

A total of 46 articles reviewed 91 cases of swidden systems being replaced with other forms of agriculture or other types of livelihood systems. Of these cases 52 document swidden being replaced by tree crops or tree-related enterprises:

- 17 document replacement by rubber trees
- 14 document swidden replaced by fruit tree cultivation (orchards)
- eight document replacement by oil palm
- six document replacement by plantation timber

Table 2 Overview of articles documenting change in swidden systems by country and activity across Southeast Asia

Swidden to	Vietnam	Laos	Cambodia	Myanmar	Thailand	Yunnan, China	Indonesia	Philippines	Malaysia
Un-managed forest	43, 44		57, 64						
Swidden, same average fallow length	32	4	57, 64		34, 39, 40	59, 64, 66	16, 17, 18, 19, 20		
Swidden, shorter fallow length	29, 30, 31, 32, 43, 57, 60, 63, 64	2, 3, 6, 7, 8, 57, 58			34, 35, 38, 39, 40, 57, 64, 67	57, 59, 64, 66	16, 17, 18, 19, 22, 33, 55		45, 46, 47, 48, 49
Coffee (1)	43								
Permanent vegetables (6)		7			34, 36, 38, 39, 41				
Oil palm (6)			57, 64				22, 33		46, 50, 51, 52
Rubber (9)	11	10, 42	57, 61, 62, 64			25, 57, 59, 64, 66	21, 22, 23, 27, 28		
Fruit trees (12)	43		61, 62		34, 36, 41		16, 17, 18, 19, 22, 7, 33, 55		
Plantation timber (incl. Teak, ecaluptus (var. sp), pine (var. sp) etc.) (6)	43, 44	1, 6, 7			24				
Permanent field crops (incl. Cotton, corn/maize, fodder crops, peanuts/groundnuts, legumes, etc.) (9)	30, 32, 43	5, 9			35, 38, 39, 57, 64			12	
Paddy/sawah (6)	30, 32						22, 27, 33	13	
Sugar cane (1)		1							
Tea (2)	43					26			
Forest/fallow cattle (1)	32								
Protected areas (6)	44				35, 36	57, 65	55	14	53
Pepper (3)							55		545, 55
Logging (2)							56		56
Opium poppy (opium replacement programs) (2)					34, 41				
Terraced agriculture (2)					34, 38				
Flower farms/greenhouse agriculture (2)					35, 36				

1—Roder *et al.* (1995); 2—Pravongviengkham (1998); 3—Roder (1997); 4—Ducourtieux *et al.* (2006); 5—Laffort and Dufurmier (2006); 6—Lestrelin *et al.* (2005); 7—Lestrelin and Giordano (2007); 8—de Rouw and Gray (2003); 9—Hansen (1998); 10—Schipani (2007); 11—Thiha *et al.* (2007); 12—Dressler (2006); 13—Dressler (2005); 14—Dressler *et al.* (2006); 15—Penot (2004); 16—Colfer *et al.* (1997); 17—Colfer and Dudley (1993); 18—Colfer (2008); 19—Dennis and Colfer (2006); 20—Dennis and Colfer (2001); 21—Colfer (1991); 22—Potter (2004); 23—Colchester *et al.* (2006); 24—Sturgeon (2005a, b); 25—Sturgeon (2006); 26—Sturgeon (2005a, b); 27—Peluso (1996); 28—Lawrence *et al.* (1998); 29—Fox *et al.* (2000); 30—Leisz *et al.* (2005); 31—Jakobsen *et al.* (2007); 32—Leisz *et al.* (2007); 33—Potter and Badock (2007); 34—Hurni (1982); 35—(Ziegler *et al.* 2004;) 36—Crooker (2005); 37—Chaplot *et al.* (2005); 38—Turkelboom (1999); 39—Ruankeaw (2004); 40—Schmidt-Vogt (1999); 41—Jones (2002); 42—Ziegler (personal communication); 43—Vu (2007); 44—Zingerli *et al.* (2002); 45—Mertz and Christensen (1997); 46—Hansen and Mertz (2006); 47—Cramb (2007); 48—Mertz *et al.* (1999); 49—Lim and Douglas (1998); 50—Nielsen *et al.* (2006); 51—Majid Cooke (2002); 52—Ngidang (2002); 53—Horowitz (1998); 54—Cramb (1993); 55—Wadley and Mertz (2005); 56—Pedersen *et al.* (2006), 57—Fox and Vogler (2005); 58—Thongmanivong *et al.* (2005); 59—Xu *et al.* (2005); 60—Fox *et al.* (2003); 61—Fox *et al.* (2008); 62—Fox (2002); 63—Fox *et al.* (2003); 64—Fox *et al.* (2001); 65—Long *et al.* (1999); 66—Xu *et al.* (1999); 67—Fox *et al.* (1995)

- three document replacement by pepper cultivation
- two document replacement by tea
- two document replacement by logging

The next greatest number of articles, 29, document swidden systems being replaced by some form of permanent, annual, agriculture. Eleven of these discuss cases of the replacement of swidden systems by permanent cultivation of field crops, such as maize, cotton, peanuts, and fodder crops; eight detail replacement by either paddy or terraced agriculture; six give examples of swidden replaced by permanent cultivation of vegetables; two provide examples of opium replacement programs replacing swidden; and two discuss cases of flower raising in greenhouses replacing swidden. These cases are spread across the region though the greenhouse and opium replacement programs are specific to Thailand.

The last major category of land use change replacing swidden systems is the replacement of these systems with protected areas. Eight articles discuss cases of this type and these are spread amongst the countries of the region.

Overall, the review of articles on swidden case studies does not show a definitive trend away from swiddening either for the region or for any of the individual countries in the region, as evidence of swidden systems persisting is found in more than half of the articles (37 of 67) and in 36% of the cases in the articles, and in 10% of the cases the fallow period is stable and not decreasing in length. However, a majority of the cases discussed (60%) document swidden systems being replaced by other forms of agriculture or by other livelihood systems and the majority of the cases where swiddening is still practiced note that the fallow length within the system is shortening. The latter may also be interpreted as a trend away from swidden, however in some cases it is observed that short fallow swidden is maintained along with other more intensive farming practices and thus not completely abandoned.

Prospective Methods for Identifying and Quantifying Swidden Systems on a Country and Regional Basis

Four prospective approaches for identifying and quantifying the extent of swidden systems at the country and regional scale are discussed. These approaches range from making use of currently available government and regional land cover maps, to using medium and small scale satellite imagery, such as Landsat, SPOT, and MODIS data, to using government census data combined with maps or satellite imagery.

Identifying Swidden Areas on Current Maps

Several researchers have noted that current government land use and land cover maps, while not explicitly identifying swidden areas, include classes of land use or of land cover that can act as proxies for areas that are dominated by swidden systems. In Vietnam the government divides upland land cover into agriculture, forest, and other categories ranging from urban land to mining and national defense lands. The forest land cover is divided into natural forest, protected forest, specialized forest, artificial forest, and hill and mountain land not yet in use (Cartography Publishing House 2002). The last category covers the largest area of the uplands and is also the area where most of the upland villages are located (Fig. 1).

Through comparing this area with known swidden areas for different regions of the country it appears that this category can act as a first proxy for estimating the extent of swidden in the uplands of Vietnam.

Time Series Analysis of Satellite Imagery to Identify Swidden Areas

After years of having been collected and archived, medium scale satellite imagery (e.g. Landsat and SPOT) is now available for many parts of the tropics in year-on-year time series for upwards of 10 years in some cases. Increasingly the utility of these data for analyzing land cover and land cover change is being considered. Budreski *et al.* (2007) use a 14 year time-series of Landsat images for the Amazon region to produce yearly maps showing cleared, re-vegetated, and primary forest areas. They show how the yearly analysis aids in distinguishing re-vegetated from primary forest areas. Leisz and Rasmussen (in press) demonstrate how to make land cover maps that accurately delineate stages of regrowth on a field after it has been cultivated by using year-on-year medium-scale satellite imagery in conjunction with a rule based classifier that uses rules derived from observed vegetation succession for a region. The stages of regrowth correspond to stages of fallow vegetation in a swidden system. Other studies (Heinimann 2006) use a robust dichotomous classification approach to land cover change. Multitemporal Landsat imagery is classified into regrowth and clearing, based on biomass indices and using object and rule based classification systems. At a certain scale of observation the resulting spatio-temporal pattern of clearing/regrowth can be seen as an indicator for shifting cultivation (Fig. 2).

Detection and Interpretation of Landscape Pattern and Mosaics

The next step in using medium-scale satellite imagery to accurately map swidden areas is to group land covers that belong to the cultivated phase of a swidden system and land covers that belong to the fallow phase of the system under a single classification label on a land use map. The main

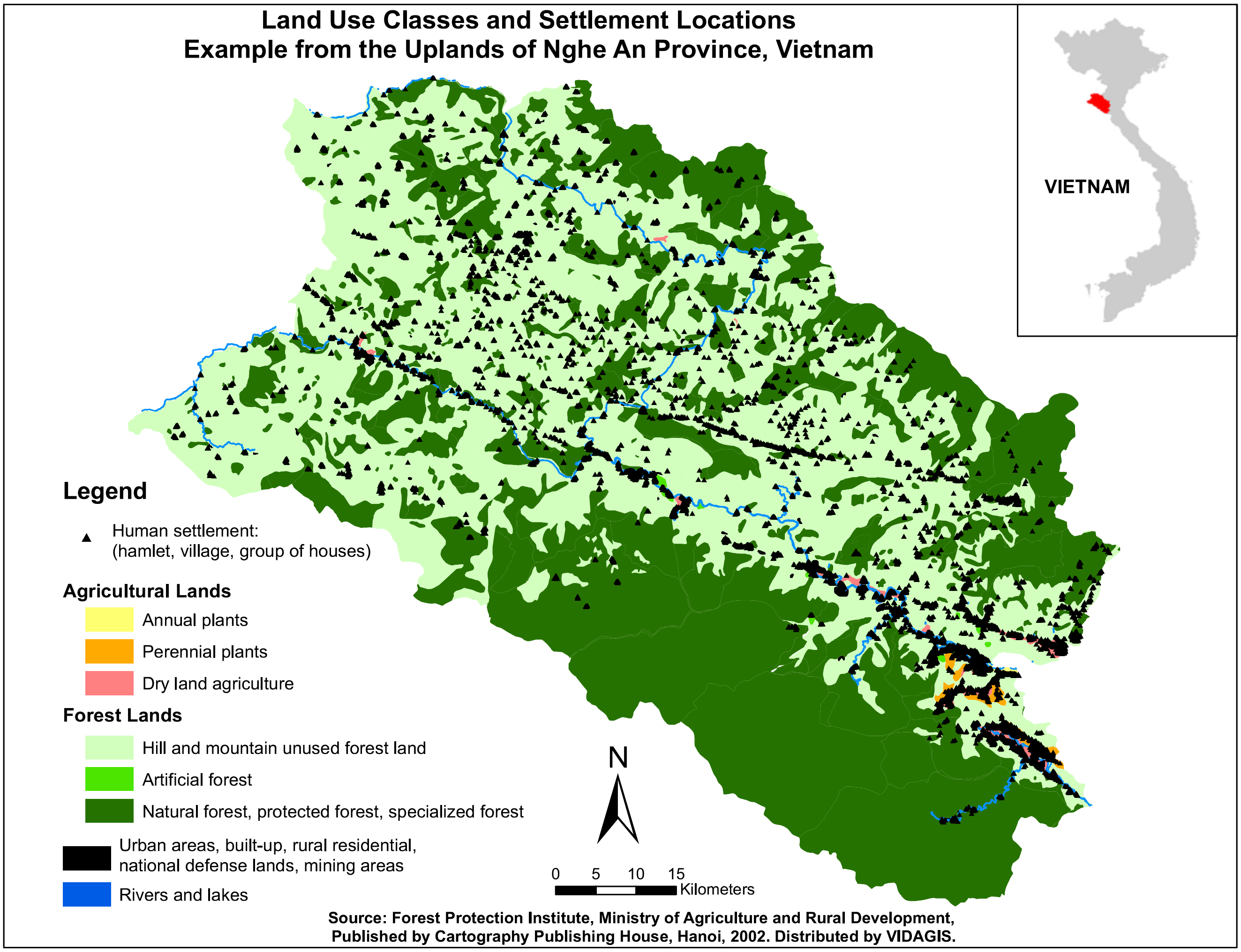

Fig. 1 Example of upland land cover and village locations in Vietnam's Nghe An Province

challenge to doing this is to link spatiotemporal patterns to processes. In the case of the above mentioned dichotomous classification approach, the geometric shapes of land cover changes and their spatial and temporal arrangement in the landscape (i.e. patterns)need to be linked to prevailing farming systems or even categories of proximate causes driving these changes. The issue of land cover pattern recognition is not a new topic, especially in the realm of landscape ecology (e.g. O'Neill *et al.* 1988; Turner *et al.* 1989; Turner 1990; Wickham and Norton 1994). When looking at images such as Fig. 2, eyes and brain of the observer have the capability to automatically segment the

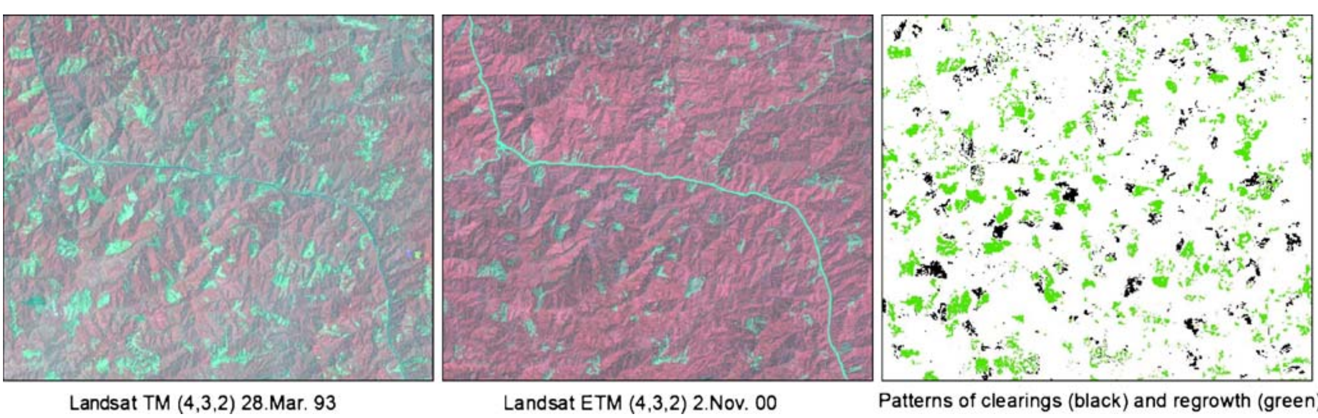

Fig. 2 Spatiotemporal patterns indicative of shifting cultivation systems

image at an appropriate scale and detect patterns which, based on pre-existing knowledge, can be related to processes. Some studies have used this approach to delineate farming system areas for parts of Southeast Asia (Leisz *et al.* 2005). The main question, however, is whether it is possible to replicate this procedure in an automated, quantitative way. The answer to date is that no operational methodological framework has been developed in land science (Heinimann 2006; Gustafson 1998). The complexity of quantifying such patterns is to a large extent related to issues of scale, resolution (spatial and temporal) and extent (O'Neill *et al.* 1996; Heinimann 2006, Riitters *et al.* 1997; Southworth *et al.* 2002; Turner and Meisel 1998; Wu 1999).

A novel approach for detecting and quantifying swidden farming systems for large areas is currently being developed by a team lead by the University of Bern, Switzerland, and is being applied to Lao PDR. This 'land cover mosaic' approach analyzes the spatial juxtaposition of different land cover types using a spatially weighted moving windows methodology. In the case of Lao PDR the existing national land cover dataset of 2002 (based on SPOT imagery) is processed and mosaics of different land cover types (e.g. shrub, grass with different forest types and patches of cultivated areas) are identified at different scales. Messerli *et al.* (2009) demonstrate that by applying this new methodology to processed land cover data, it is possible to detect and spatially delineate swidden areas in the uplands of Lao PDR.

Integrating Census Information Into Land Use Classifications

Most current population censuses classify people by their occupation. People, both in the lowlands and uplands, are classified as 'farmers', when their activities are tied to agricultural practices. It is hypothesized here that swidden farming systems could be delineated by analyzing current land cover maps in conjunction with population maps providing information on the percentage of farmers per unit of area. Swidden areas could be estimated for upland regions based on an analysis of the extent of land classified as 'agricultural land', the extent of land classified as different types of 'forest cover' and the number of farmers. To 'sharpen' the identification of swiddeners based on household characteristics, agricultural censuses can be tapped. Integrating such analysis with either the land cover mosaic analysis or the year-on-year time series satellite analysis could provide an even more robust analysis of the extent of swidden at a country or regional scale.

The four approaches presented show that the quantification of swidden on a wider spatial scale necessitates innovative methods that allow combining environmental as well as socio-economic data at different scales. The success of such endeavors not only depends on novel approaches, but also on the availability of accurate data, particularly when it comes to national or regional studies. The development of prospective methods should therefore be driven by the type and scale of data that is being generated by other national or regional initiatives. In this regard, the recent selection of Vietnam and Lao PDR to participate in the World Bank's forest carbon fund is particularly noteworthy. Such countries are given the difficult task of trying to determine the present state of their forests in order to measure future deforestation rates. Linking the quantification of swidden systems to such initiatives would not only offer methodological and financial synergies, but also bears the potential of revealing ecosystem services provided by swidden systems that have so far gone unnoticed and hence unrewarded. The consequences of trends in swidden cultivation on carbon storage are discussed in Bruun *et al.* (2009).

Conclusion and Research Needs

We have shown that there is a surprising lack of conclusive data on the extent of swidden systems in Southeast Asia. Such data are essential if development in rural areas currently and formerly dominated by swidden is to achieve the international goals of reducing poverty, strengthening local livelihoods, and maintaining ecosystem services. Without an adequate understanding of the extent of the area under swidden and of the current trends of swidden, development organizations will be working in the dark and could propose solutions that are not viable.

A wide range of remote sensing based techniques are available for assessment of local level change in land cover, and potentially, as described above, in swidden land use, but the complexity and dynamic nature of swidden makes assessments on a wider scale more complicated. Combining such tools with demographic data, ethnographic studies, and spatial information databases will make it possible to obtain a better picture of the current area under swidden as well as the number of people depending fully or partially on this system for their livelihoods. A further need is to improve the knowledge, awareness, and commitment to understanding land cover and land use complexity that government agents and scholars bring to the task of categorizing land uses found in the uplands of Southeast Asia. With a concerted effort we can document the range of areas where swidden is found and the changes that are taking place on these landscapes and their profound environmental and social implications.

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