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A Regional-scale Analysis

Secondary forests in the Lower Mekong Basin (LMB) are increasingly recognized as a valuable component of land cover, providing ecosystem services and benefits for local users. A large proportion of secondary forests in the LMB, especially in the uplands, are maintained by swidden cultivation. In order to assess the regional-scale status and dynamic trends of secondary forests in the LMB, an analysis of existing regional land cover data for 1993 and 1997 was carried out and forms the basis of this paper. To gain insight into the full range of dynamics affecting secondary forests beyond net-change rates, cross-tabulation matrix analyses were performed. The investigations revealed that secondary forests make up the largest share of forest cover in the LMB, with over 80% located in Laos and Cambodia. The deforestation rates for secondary forests are 3 times higher than the rates for other forest categories and account for two-thirds of the total deforestation. These dynamics are particularly pronounced in the less advanced countries of the LMB, especially in Laos, where national policies and the opening up of national economies seem to be the main drivers of further degradation and loss of secondary forests.

Keywords: *Secondary forests; land cover change; deforestation; swidden cultivation; Lower Mekong Basin.*

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Introduction

Secondary forests are an important though often underrated component of tropical landscapes. It is estimated that they account for over 30% of tropical forest area and that their share is increasing (Emrich et al 2000). As forests related to disturbances originating from human interventions such as logging, shifting cultivation, forest grazing, etc, they are tainted with the reputation of being degraded and therefore less valuable than primary, ie original or undisturbed forests. The term "degradation" subsumes features of inferiority such as lower biodiversity, reduced structural complexity, and lower proportions of economically valuable species or economically viable tree sizes.

Research has shown, however, that at least some secondary forests can be as diverse and complex as primary forests, and that many are capable of playing a significant role in delivering ecosystem services and contributing to people's livelihoods, especially in mountain areas. In the Lower Mekong Basin (LMB), secondary forests are part of a highly diverse and dynamic landscape. Studies from this region point to the importance of secondary forests and their appropriate management (Fox et al 2000). However, most research carried out on secondary forests in particular—and on land cover dynamics in general—consists of local case studies. Hence the information generated is bound to the respective specific context and basically cannot be generalized, leading to the "ideographic trap" inherent in sustainability research (Hurni and Wiesmann 2004). On the other hand, the available regional-scale information per se is generally rather rudimentary. The widely available large-scale land cover inventories are frequently not exploited to their full potential due to a lack of appropriate methods and institutional obstacles related to the mandates of the respective data producers. Consequently, there is a lack of regional-level estimates about the status and dynamics of secondary forests in the LMB. This is a serious deficit, especially in the context of the highly heterogeneous and economically interlinked riparian countries of the LMB (Laos, Thailand, Cambodia, and Vietnam), where policies relating to environmental management need to be designed from a regional perspective involving transboundary aspects.

Against this background, the present study attempts to generate spatiotemporally comparable information and knowledge about the status, dynamics, and role of secondary forests for the entire LMB through a mesoscale analysis of available land cover inventories. The best regional inventory currently available is contained in the MRC/GTZ land cover datasets, which, however, date back to 1993 and 1997. The decision to use these datasets for an assessment of land cover change is based on the knowledge that no other data would allow a comparable multi-temporal analysis to be carried out for the entire LMB. We acknowledge that the use of 10-year-old data from a region that is changing rapidly requires a cautious approach to designing policy recommendations on the basis of these data. However, our experience and further research in the region has shown that analysis of these data can produce highly relevant insights for the present: First, the dynamics of secondary forests can be retraced; such dynamics are the outset of more recent developments. Second, there are clear indications that trends captured in the MRC/GTZ datasets are still ongoing and are therefore sufficiently indicative of future trends (Heinimann 2006). Finally, such an analysis makes it possible to suggest important recommendations about the design of future land cover inventories and monitoring campaigns by state actors and international organizations.

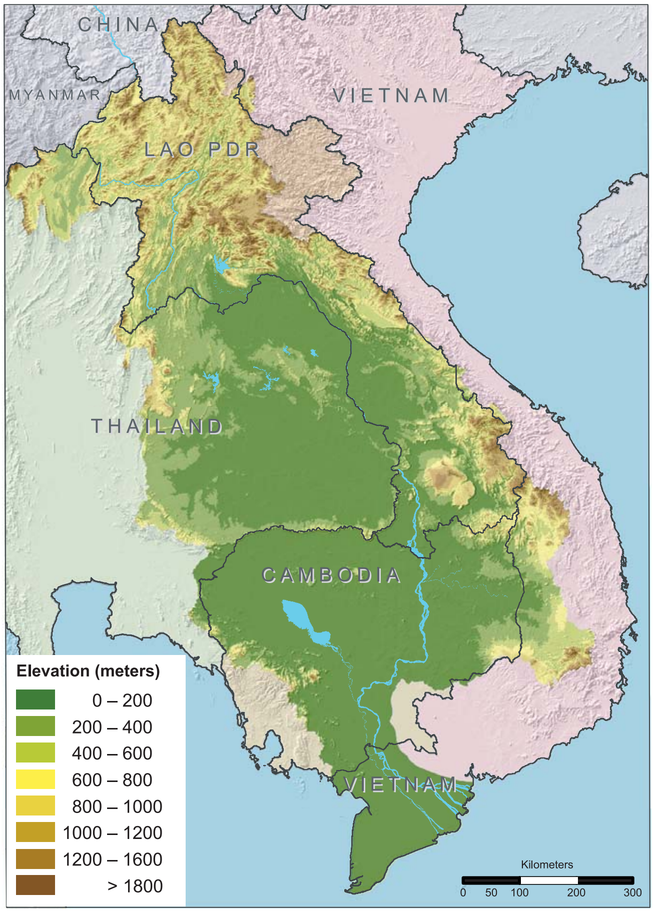
The study area

The Lower Mekong Basin (LMB) comprises parts of Laos, Thailand, Cambodia, and Vietnam, and covers 620,000 km^2 of mainland Southeast Asia (Figure 1). Myanmar's small share of the LMB (3% of the entire Mekong Basin) is not included in this study. The LMB is home to roughly 60 million people. About 80% of the population are predominantly rural and rely heavily on natural resources for their livelihood. Distribution of the population varies greatly across and within the riparian countries: the Mekong Delta, the Vietnamese Central Highlands, and the Khorat Plateau in Thailand are far more densely populated than large parts of Cambodia and especially Laos. Physiographic features include uplands with peaks up to 2900 m in northern and northeastern Thailand, eastern and southwestern Cambodia, and extending along the entire length of Laos and Vietnam, as well as lowlands in the Cambodian floodplains and the Mekong Delta in Vietnam (Figure 1).

The tropical monsoon climate of the LMB is characterized by a distinct dry season from November to May, and a rainy season from June to October. The average annual rainfall varies from 1300 mm on the Khorat Plateau in northeastern Thailand to over 3000 mm in the highlands of northern Laos and in the Elephant and Cardamom mountain ranges in southwestern Cambodia (MRC 2003). With the exception of a few isolated areas of rock outcrops and water bodies, the natural vegetation cover under such conditions is tropical forest. The basic precipitation-related distinction is between evergreen, deciduous, and dry forest types. Evergreen forests occur throughout the entire altitudinal range from tropical lowland to tropical montane. Deciduous and dry forests are limited to the drier parts of the lowlands and the foothill zone (Vidal 1997).

Rapid and widespread land cover changes have deprived Thailand and Vietnam of large parts of their original forests. The 2 less-developed countries in the center of the Basin, Cambodia and Laos, are still comparably well endowed with forest resources. The ongoing economic opening-up of Cambodia and Laos as a result of national policies, the enormous economic development, and continuous population growth in the entire region, exert an ever-increasing pressure on the remaining forests in the center of the Basin. Examining the extent to which this pressure also affects secondary forests is one of the main objectives of our research.

FIGURE 1 Overview of the riparian countries of the Lower Mekong Basin. (Map by Andreas Heinimann)



Secondary forests in the LMB: ecology and functions

Secondary forests have been defined as:

> "forests regenerating largely through natural processes after significant human disturbance of the original forest vegetation after a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy composition with respect to nearby primary forests on similar sites" (Chokkalingam et al 2001).

Secondary forests in the LMB result mainly from commercial and illegal logging, and from swidden farming. According to Mittelman (2001), logging is the predominant cause of secondary forest formation in the lowlands, while swidden farming is predominant in the uplands. A crucial factor in the creation of secondary forests is fire. Fire is an inherent component of swidden farming systems, but also occurs for a variety of other reasons—natural and anthropogenic—and affects mainly deciduous broadleaved forests, dry forests, and pine forests. Swidden farming is the traditional form of land use in the uplands of the LMB; it is apparently still widespread, despite a region-wide trend to adopt or impose adoption of more intensive and permanent forms of land use (Schmidt-Vogt 2000). Swidden farming can be divided into 2 main types: short-cultivation swiddening and long-cultivation swiddening (Hansen 2001). Long-cultivation swiddening usually produces secondary vegetation dominated by scrub or grasses (including bamboo), while short-cultivation swiddening with long fallow periods leads to the development of secondary forests or swidden fallow forests according to the terminology of Chokkalingam et al (2001). Swidden farming maintains a landscape mosaic of rotating patches in a continuous state of flux: secondary forests are regenerated in a continuous cycle of successional stages, ranging from early weed-dominated stages to scrub and finally forest stages.

The condition and the internal dynamics of secondary forests are determined by a variety of factors: fallow length and land use techniques in the case of swidden fallow forests, intensity and frequency of disturbances such as fire, site conditions, proximity of seed source and presence of wildlife, and extraction of wood products and NTFPs. The quality of secondary forests and their potential to provide a wide range of ecosystem services and other benefits have been underrated in the past. This is especially true of swidden fallow forests, which most probably constitute the largest share of secondary forests in the LMB. Schmidt-Vogt (1998, 1999) has shown that fallow forests in short-cultivation swiddening systems can be characterized by a high level of biodiversity as well as by functional diversity: besides their main role in swidden farming systems of building up a stock of nutrients in their biomass, which is then released by burning before the next cropping phase, they provide watershed protection and habitat, contribute to soil conservation, and supply products to local users.

There are also examples of farmers enhancing the economic value of fallow forests by increasing the proportion of commercially useful species, eg through enrichment planting with *Styrax tonkinensis* trees, producing a resin for lacquer production in Laos (Fischer et al 2007). Examples such as these point towards the potential of fallow forests in particular, and secondary forests in general, to contribute to the diversification of local economies and the improvement of livelihoods. Secondary forests already form a basis for the livelihoods of millions of people throughout the Basin (MRC 2003; Lang and Shoemaker 2006). In their study of the conservation value of swidden cultivation landscapes, Finegan and Nasi (2004) come to the conclusion that, while biodiversity on the landscape scale is upheld by the mosaic character of swidden landscapes, it is the secondary forest components of this mosaic—especially the mature secondary forests—that play an especially important role because of their significance for the conservation of forest-dependent biodiversity.

The case of swidden landscapes highlights the fact that secondary forests are often components of landscapes characterized by a high degree of diversity and dynamics. There is evidence, however, that land use dynamics in the LMB are posing a threat to secondary forests. As most of this evidence is anecdotal in character or limited to case studies, an attempt is made here to analyze land cover change processes on a mesoscale level to assess the status and dynamics of secondary forests for the entire LMB.

Methods

In a regional, transboundary context most of the available national land cover inventories cannot be used to gain insight into past land cover dynamics for the entire area under investigation, as the national inventories were produced using different data sources and methods. Hence, the guiding principle of this paper is to exploit already existing regional datasets to provide a quantitative regional assessment of secondary forest resources for the entire LMB. An evaluation of the different available and spatiotemporally comparable regional datasets for the LMB revealed, in line with findings of other authors (Mittelman 2001; MRC 2003; Heinimann 2006), that the land cover datasets of MRC/GTZ for 1993 and 1997 (MRC and GTZ 1998) still contain the currently most reliable comparative and multi-temporal land cover information for the entire Basin. These data were elaborated based on visual interpretation of Landsat TM data at a nominal scale of 1:250, accompanied by extensive field verifications (Stibig 1997) within a 6-year initiative (US$ 3.2 million) of the Mekong River Commission (MRC) funded by the German Agency for Technical Cooperation (GTZ).

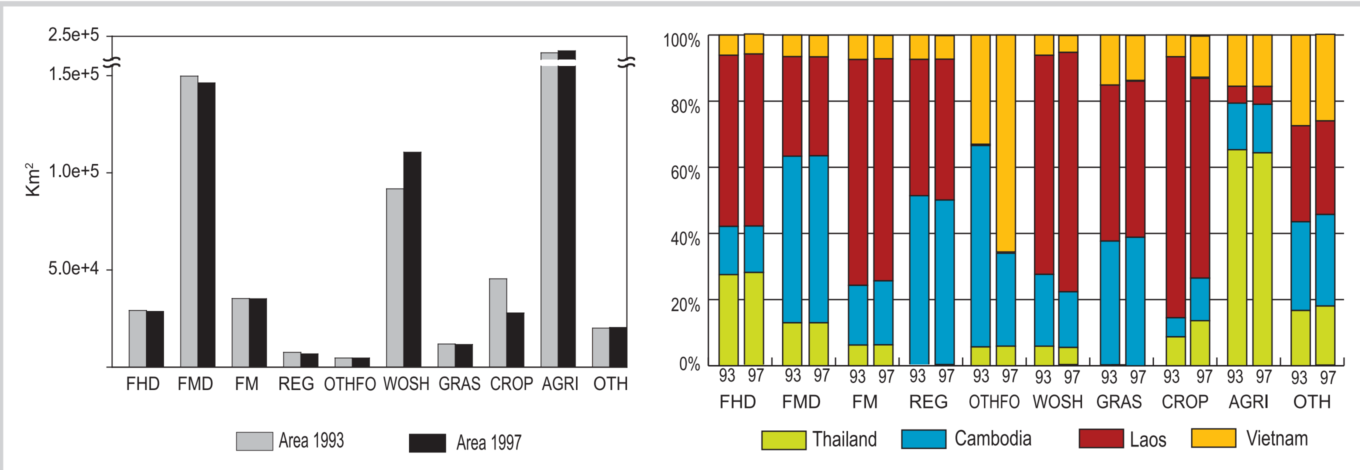
A problem in using this dataset was that secondary forests were not delineated as a separate aggregated forest class. For the purpose of this study, it was therefore assumed that the categories "medium to low cover density" (FMD)—characterized by a canopy density of 20 to 70%—and "forest mosaics" (FM) are to a large extent of secondary nature and can be considered to represent secondary forests. This assumption is based on observations in the field concerning the generally open and fragmented nature of secondary forest complexes made by the authors throughout the Basin over the last 10 years. We acknowledge, however, that a certain margin of error may be due to the fact that some dry and deciduous forests in the foothills and low-

TABLE 1 Land cover dynamics in the Lower Mekong Basin, 1993–1997. Bold figures indicate land cover classes considered as secondary forests. FHD: Forest, high density; FMD: Forest, medium–low density; FM: Forest mosaic; REG: Regrowth; OTHFO: Other forest; WOSH: Wood- & shrubland; GRAS: Grassland; CROP: Mosaic of cropping; AGRI: Agricultural land; OTH: Other. (Based on MRC/GTZ land cover datasets)

Land cover class		Area in 1993 [× 1000 km²]					Net change 1993–1997 [× 1000 km²]				
		Camb	Laos	Thai	Viet	LMB	Camb	Laos	Thai	Viet	LMB
Forest	FHD	4.2	15.1	8.0	1.8	29.2	–0.22	–0.17	–0.05	–0.04	–0.48
	FMD	**75.5**	**45.1**	**19.4**	**9.8**	**149.8**	**–1.58**	**–1.24**	**–0.46**	**–0.21**	**–3.48**
	FM	**6.4**	**24.1**	**2.2**	**2.6**	**35.3**	**0.45**	**–0.40**	**0.02**	**–0.12**	**–0.06**
	REG	3.9	3.1	0.0	0.6	7.6	–0.48	–0.21	–0.01	–0.08	–0.77
	OTHFO	2.9	0.0	0.3	1.6	4.7	0.00	0.00	0.01	–0.03	–0.01
No forest	WOSH	19.9	60.8	5.4	5.6	91.8	–1.30	19.77	0.28	0.06	18.88
	GRAS	4.4	5.6	0.0	1.8	11.9	0.09	–0.10	0.00	–0.21	–0.22
	CROP	2.6	35.9	4.0	3.0	45.4	0.97	–18.50	–0.17	0.17	–17.53
	AGRI	31.2	11.3	144.8	34.4	221.6	1.81	0.90	0.08	0.63	3.42
	OTH	5.4	5.8	3.4	5.5	20.1	0.26	–0.06	0.29	–0.16	0.33
	Cloud & No data	0	0.4	0.6	0.4	1.4					
Total area		*156.4*	*207.2*	*188.1*	*67.0*	*618.8*					

Land cover class		Percentage of total area in 1993 (see total in italics above)					Net change 1993–1997 [in % of 1993 area]				
		Camb	Laos	Thai	Viet	LMB	Camb	Laos	Thai	Viet	LMB
Forest	FHD	2.7	7.3	4.3	2.7	4.7	–5.2	–1.1	–0.6	–2.5	–1.7
	FMD	**48.3**	**21.8**	**10.4**	**14.7**	**24.2**	**–2.1**	**–2.7**	**–2.3**	**–2.2**	**–2.4**
	FM	**4.1**	**11.7**	**1.2**	**3.9**	**5.7**	**7.0**	**–1.7**	**0.8**	**–4.7**	**–0.2**
	REG	2.5	1.5	0.0	0.9	1.2	–12.4	–6.7	–20.9	–13.2	–10.3
	OTHFO	1.9	0.0	0.1	2.3	0.8	0.1	0.0	4.0	–1.6	–0.2
No forest	WOSH	12.7	29.4	2.9	8.4	14.9	–6.5	32.5	5.1	1.0	19.9
	GRAS	2.8	2.7	0.0	2.7	1.9	2.0	–1.8	13.3	–11.9	–1.8
	CROP	1.7	17.3	2.1	4.5	7.4	36.9	–51.6	–4.2	5.6	–39.7
	AGRI	19.9	5.5	77.2	51.6	35.9	5.8	8.0	0.1	1.8	1.5
	OTH	3.4	2.8	1.8	8.3	3.3	4.8	–0.9	8.6	–3.0	1.6
Total		100.0	100.0	100.0	100.0	100.0					

FIGURES 2A AND 2B A) Dynamics of selected land cover classes in LMB, 1993–1997. B) Proportions of selected land cover classes in the riparian countries in 1993 and 1997.



lands, which are not necessarily secondary in nature, can be quite open, and, conversely, that some secondary forests can be dense.

A similar approach was followed by Mittelman (2001) in his analysis of secondary forests of the Lower Mekong Subregion. Our approach differs from Mittelman's in that we do not limit ourselves to secondary forests and the related aggregated change trajectories, but broaden our view to consider the entire spectrum of land cover classes and land cover change trajectories in order to get a fuller picture of ongoing processes. To capture the entire dynamics of the secondary forest system, and not only the net-change portion, cross-tabulation matrix techniques and swap dynamic analyses were performed for all land cover types.

Apart from the secondary forest classes mentioned, the following land cover classes were considered:

- Dense forests (FHD) with a crown cover of more than 70%;
- Forest regrowth (REG), which stands for a continuous and usually rather dense layer of small trees;
- Wood- and shrublands (WOSH), which include bamboo, scrub, and small trees growing on recently abandoned swidden fields;
- Other forest (OTHFO), eg plantations;
- Grassland (GRAS);
- Cropping mosaic (CROP), which contains a mixture of fields currently under cropping or in various stages of fallow covered with shrubs or woody biomass;
- Permanent agricultural land (AGRI); and
- Other land cover types (OTH).

In terms of the main land cover change categories considered, the current paper understands deforestation as the conversion from forest to no-forest classes (eg FHD to CROP), while forest degradation basically refers to a decrease in crown cover density (eg transformation of FMD to FM).

The status and distribution of secondary forests

Secondary forests covered 30% (185,000 km^2) of the entire land surface and accounted for well over 70% of the entire forest cover of the LMB in 1993 (Table 1 and Figure 2A). Medium- to low-density forests (FMD) were, after agricultural lands, the single most important land cover, covering almost a quarter of the entire LMB (Table 1). Of the total secondary forest surface in the LMB, Cambodia and Laos together hosted the largest share, amounting to 81% (44% and 37%, respectively) (Figure 2B). While most medium- to low-density forest (FMD) was located in Cambodia (50%), the largest shares of forest mosaic (FM) occurred in Laos (68%).

The share of WOSH, and to some extent of CROP, may serve as an indicator of the status of agricultural development if compared to the share of AGRI in the various riparian countries: large-scale expansion of permanently used agricultural lands, resulting in the conversion of WOSH and CROP to more intensive forms of land use, has taken place in Thailand and Vietnam during the last 20 to 25 years. In Laos and Cambodia, on the other hand, agricultural expansion has taken place on a much smaller scale (Heinimann 2006). There are, however, indications that in Laos and Cambodia this process has accelerated significantly since the end of the assessment period (1993–1997) (MRC 2003). This has implications for the future of secondary forests as well. If utilized at a low level of intensity, most

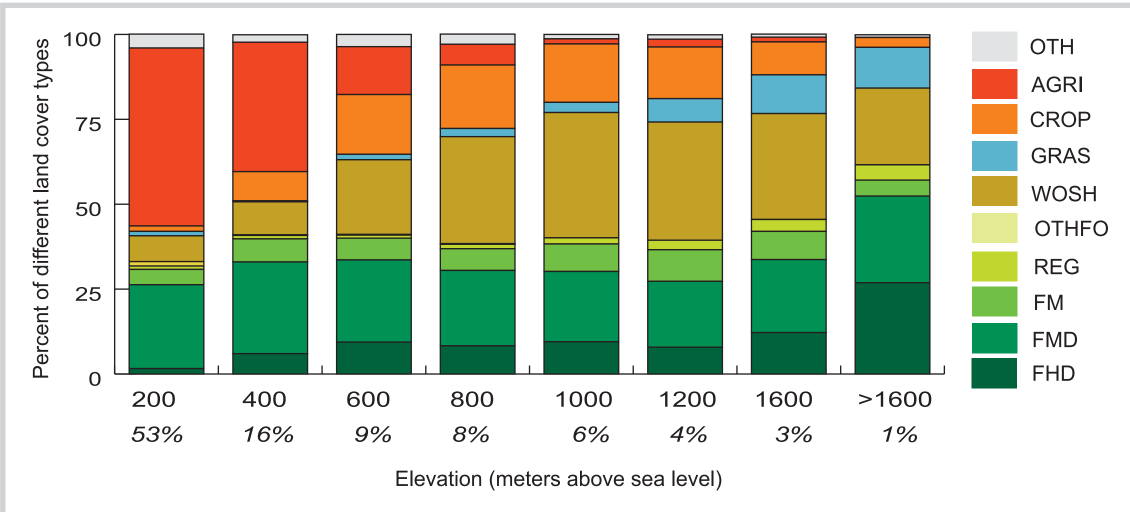


FIGURE 3 Distribution of different land cover classes (1993) along the elevation gradient. Full percentage (100%) refers to each elevation class.

WOSH, and to some degree CROP, can develop into secondary forests within a relatively short time (10–20 years). Converting CROP and WOSH to more intensive forms of land use can therefore also mean loss of potential secondary forests.

Relatively undisturbed dense forests (FHD) constituted only 13% of the entire forest area in the Basin. Most of this forest is located in Laos and Thailand. It is also noteworthy that in Thailand—as compared to the other countries—almost 27% (or 30,000 km^2) of the relatively small remaining overall forest cover in 1993 was of a dense nature, which is almost twice as much as in all other riparian countries.

No clear tendencies can be observed with respect to the distribution of secondary forests along an altitudinal gradient (Figure 3). In all elevation zones the share of secondary forests ranges between 28% and 34%, thus remaining fairly constant. The only tendency that can be detected is that at elevations where mosaics of cropping (CROP) and wood- and shrublands (WOSH) account for a considerable proportion (800–1600 m), the share of secondary forest is slightly lower. This highlights how closely secondary forests are interwoven with swidden agricultural practices underlying the genesis and “maintenance” of the WOSH and CROP system. The critical question of how much wood- and shrubland is actually involved in the swidden cycle cannot be answered due to data limitations.

Dynamics of secondary forest in the LMB

The analysis of the net dynamics of the secondary forest classes between 1993 and 1997 shows that while almost 3500 km^2 or 2.4% of medium- to low-density forests (FMD) have disappeared, the area of forest mosaic (FM) has remained almost stable on a region-wide scale (Table 1). Differentiating the net change of FM on a country level, however, reveals that the considerable losses in this class occurring in Laos and Vietnam were compensated for by increases of FM in Cambodia (mainly due to conversion of FMD to FM as a result of forest degradation). This highlights that standard net-change analysis of secondary forest changes is far from sufficient to reveal the entire complex of ongoing dynamics.

To gain insight into the full range of dynamics affecting secondary forests, class-specific cross-tabulation matrix analyses were carried out (Table 2). Cross-tabulation shows that the actual dynamics (gains plus losses) in the secondary forest classes (FMD but especially FM) are in fact much higher than the net-change analysis in Table 1 can capture. One may argue that this is not relevant since only the actual area of the secondary forest classes lost due to deforestation matters. This, however, is not entirely correct, as the largest share of the gains of the secondary forest types are either based on forest degradation from FHD to FMD (11% of all gains) or from FMD to FM (71% of all gains). This is relevant, as it is likely that these forests will continue their trajectory of degradation, which could eventually lead to complete deforestation.

To capture and grant easy access to those parts of the dynamics that are ignored by classical net-change analysis of land cover change, Heinimann (2006) has proposed to indicate for each land cover type which portion of the entire dynamics observed in a land cover type has led to actual net change, and, conversely, which portion is ignored when only net change is considered (Table 3).

TABLE 2 Cross-tabulation matrix of the land cover changes in the LMB between 1993 and 1997 in km². The 1254 km² covered by clouds in 1997 were assumed to have remained stable. (Source: Heinimann 2006; based on MRC/GTZ land cover datasets)

	1997												
1993	FHD	**FMD**	**FM**	REG	OTHFO	WOSH	GRAS	CROP	AGRI	OTH	Total 1993	**Loss**	**% Loss**
FHD	28,670	**215**	**94**			34		92	44	5	29,153	484	1.7
FMD		**145,871**	**1,362**			**564**	**21**	**1,494**	**464**	**25**	**149,800**	**3,929**	**2.6**
FM			**33,739**		**3**	**249**	**23**	**987**	**253**	**27**	**35,281**	**1,542**	**4.4**
REG	2	**233**	**20**	6,733		309	14	277	31	12	7,630	897	11.8
OTHFO			**5**		4,300	3	13	2	162	226	4,711	411	8.7
WOSH				100	3	84,876	135	4,815	1,650	224	91,804	6,928	7.5
GRAS					8	3	11,046	292	435	87	11,872	826	7.0
CROP				23		24,558	44	19,833	975	9	45,443	25,610	56.4
AGRI					239	7	354	14	220,269	711	221,594	1,325	0.6
OTH	1				146	12	5	102	731	19,084	20,082	998	5.0
Total 1997	28,673	**146,319**	**35,219**	6,857	4,699	110,616	11,654	27,907	225,014	20,411			
Gain	4	**448**	**1,481**	124	399	25,740	608	8,074	4,745	1,327			
% Gain	0.0	**0.3**	**4.2**	0.0	8.5	28.0	5.1	17.8	2.1	6.6			

This portion is referred to as "swap dynamics," following Pontius et al (2004). The left side of Table 3 illustrates the portions of the total land cover dynamics in the LMB that can be captured by classical net-change analysis, while the right side shows the portions of the dynamics usually ignored by standard analysis. This analysis (Table 3) reveals for example that 98% of the dynamics of FM are not captured by the usual standard net-change assessments. The loss of 1542 km² (or 4.4% of the area in 1993) is "neutralized" by gains mainly due to forest degradation (1481 km² or 4.2%), resulting in a net change of 61 km² or only 2%.

In what follows, the transformations of the 2 forest cover classes considered as secondary forests (FMD and FM) will be examined in greater detail. "High-density forests" (FHD) is included in order to contextualize the changes detected in secondary forests.

Forest, high density (FHD)

Compared to other forest types, FHD areas were rather stable with an overall net decrease of –1.7% from 1993 to 1997. This decrease was principally due to a net loss, as there was virtually no increase and therefore almost no swap dynamics throughout the Basin (Tables 2 and 3). On a Basin level, most losses of FHD (309 km² or 64%) are due to forest degradation processes that lead to reclassification in the next lower density class, and hence to an increase in secondary forests as defined above. The differences among the riparian countries, however, are considerable. According to additional country-specific analyses carried out by Heinimann (2006) on the basis of the same data sources, losses in Cambodia are mainly related to forest degradation (88%), while in Thailand 60% of losses are due to deforestation.

Forest, medium to low density (FMD)

On a Basin level, dynamics related to FMD account for over 80% of all forest degradation observations and almost 50% of all deforestation observations (Table 4). Two-thirds of the FMD losses are due to deforestation while only one-third is caused by forest degradation; deforestation processes are of even greater importance in Thailand and Vietnam. Most FMD was transformed to cropping mosaic (1500 km²) and wood- and shrubland (564 km²). It is, however, noteworthy that a considerable share of FMD (464 km² or 12% of the total loss of FMD) is directly transformed to permanent agricultural areas; 50% of this trajectory is taking place in Thailand, where national policies aiming at reducing swidden farming practices, and market opportunities for cash crops have furthered the direct conversion of forest to permanent farmland for 2

TABLE 3 Swap dynamics in selected land cover classes by country in the LMB (1993–1997). (Based on MRC/GTZ land cover datasets and Heinimann 2006)

Land cover class	Percentage of total dynamics manifested as net change					Percentage of swap dynamics				
	Camb	Laos	Thai	Viet	LMB	Camb	Laos	Thai	Viet	LMB
FHD	100	97	95	100	99	0	3	5	0	1
FMD	80	74	96	85	80	20	26	4	15	20
FM	47	25	11	43	2	53	75	89	57	98
REG	92	50	100	100	76	8	50	0	0	24
OTHFO	1	–	58	4	1	99	–	42	96	99

TABLE 4 Relative contribution of the various forest classes to overall deforestation and forest degradation in the LMB (1993–1997). (Based on MRC/GTZ land cover datasets and Heinimann 2006)

Land cover class	Deforestation (%)					Forest degradation (%)				
	Camb	Laos	Thai	Viet	LMB	Camb	Laos	Thai	Viet	LMB
FHD	1	5	6	3	3	22	12	19	28	18
FMD	56	43	78	23	48	78	88	78	72	82
FM	13	48	14	27	29	0	0	3	0	0
REG	25	4	1	7	12	0	0	0	0	0
OTHFO	5	0	1	40	8	0	0	0	0	0
Total	100	100	100	100	100	100	100	100	100	100

decades (Mittelman 2001; Schmidt-Vogt 2001; Rasul and Thapa 2003).

Forest mosaics (FM)

"Forest mosaics" is, by its very nature, a highly dynamic class, with 9% of the total area (gains and losses) involved in some form of change between 1993 and 1997. In Cambodia alone, the area of FM increased by 445 km^2 between 1993 and 1997 (mainly due to further progress along the degradation continuum from FHD to FM), while in all other riparian countries the area of FM decreased. The respective share of Basin-level swap dynamics was very large, accounting for 98% of the total dynamics (Table 3). Due to the marked Basin-level swap dynamics, the net change was therefore 25 times smaller than the actual loss occurring (loss of 1540 km^2 instead of a net change of 61 km^2) (Tables 1 and 3). The contribution of FM losses to the overall deforestation in the Basin was substantial, amounting to 29% (Table 4). The fact that most of the deforestation affecting FM is taking place in Laos (48%) is mainly due to the fact that this class covers 11% of the country's surface area, accounting for 68% of all FM in the Basin. In all riparian countries the dominant deforestation trajectory of FM is transformation to CROP, primarily because forest mosaics form, to some extent, an integral part of swidden systems. Similar to FMD, considerable shares of FM are directly transformed to agricultural land in Thailand (37% of the total loss of FM in Thailand). Also in Cambodia, already one-third of the losses of FM are transformations to agricultural lands.

To summarize the entire dynamics on an aggregated level for secondary forests (FHD and FM), the present research has highlighted that the largest share of all deforestation (77% or 4107 km^2) and forest degradation (82% or 1382 km^2) processes in the LMB affect secondary forests (Table 2). Additionally, in terms of relative change rates (1993–1997), deforestation rates are over 3 times higher in secondary forests (2.2%) than in dense forest (0.6%) (Table 2). Loss of secondary forest in the LMB is mainly related to transformations to "mosaic of cropping" and "wood- and shrublands" (80%). Because of the regional nature of the data, it is impossible to assess the extent to which deforestation is due to swiddening or to commercial logging processes. It is, however, possible to show that agricultural expansion in the LMB in most cases is a 2-step process, with deforestation, ie conversion of secondary forests to WOSH and CROP, being followed by intensification processes leading to permanent agricultural lands. This is in line with other studies (Kaimowitz 2000; Geist and Lambin 2001), which indicate that logging paves the way for agricultural expansion. In Thailand, on the other hand, where agriculture, even in the uplands, is already commercialized to a large extent (Schmidt-Vogt 2000), deforestation is a one-step process of direct conversion of secondary forest to permanent agriculture (Heinimann 2006). In the context of the LMB it can be anticipated that, due to economic and environmental policies, the direct transformation of secondary forests to agricultural lands—including industrial plantations such as rubber—will accelerate, as is currently the case in Laos (Thongmanivong and Fujita 2006).

Conclusion

The present study has focused on dynamics of secondary forests in the LMB, which play a crucial role in the complex rural landscapes of tropical countries. On the one hand, these forests are important for the livelihoods of the rural poor, who obtain from them a wide range of products for their immediate and most basic needs and also manage them for marketable goods. On the other hand, secondary forests provide ecosystem services that usually go unrecognized, and help to maintain biodiversity by providing habitat.

The analysis of the MRC/GTZ regional land cover data has revealed considerable secondary forest dynamics between 1993 and 1997. While secondary forests in the LMB covered a much larger area than other forest categories, they were at the same time decreasing at a higher rate. Between 1993 and 1997, agricultural land in the LMB has been expanding at a significant rate, transforming secondary forests into swidden farming or permanent agriculture. Whereas high-density forests have seen comparatively low dynamics, medium- to low-density forests have experienced the greatest losses, accounting for 80% of total deforestation and 50% of forest degradation processes in the LMB.

The high rates of change in secondary forests could only be revealed by applying cross-tabulation matrix techniques, showing that a considerable share of the loss is being compensated by the degradation of less disturbed forest categories. Hence, the present study highlights the importance of mesoscale approaches to land cover change, revealing dynamics beyond classical regional net-change investigations or highly site-specific local analyses.

The revealed dynamics affecting secondary forests manifest a clear spatial pattern. On the one hand, conversion rates were clearly higher in Laos and Cambodia than in Thailand and Vietnam. On the other hand, it was shown that in Thailand and Vietnam higher shares of secondary forests were converted into permanent agriculture, whereas in Laos and Cambodia the dominant pathway consists of forest degradation followed by conversion to swidden and later to permanent farming. In terms of biodiversity conservation and livelihood security of the rural poor, these processes are highly alarming, especially in the more vulnerable mountain areas. Not only does the apparent stability of certain forest classes hide tremendous deforestation and degradation processes, but poor farmers also lose an important component of their farming system.

This double periphery may best be illustrated by current developments in Laos, where the government, in an overall strategy to regain a 70% forest cover, mainly through plantation forestry, allows provincial authorities to issue leases to private enterprises in neighboring China, Vietnam, and Thailand for rubber, eucalypt, or coffee plantations, etc. Similar developments are reported for neighboring parts of China by Xu (2006). To this purpose the respective governments classify secondary forests as "degraded forest," making conversion into monoculture plantations possible. One-dimensional land use decisions such as these, where manifold environmental functions of secondary forests are sacrificed for a single and short-term production function, are symptomatic not only of Laos but also of other parts of the LMB.

Future research oriented towards sustainable development in the LMB should therefore recognize that secondary forests are a key element when it comes to shaping realistic and equitable development pathways allowing for economic growth balanced with environmental sustainability. In this regard, 2 research fields seem to be of particular importance. First, classification and assessment of different secondary forest types with a view to studying their environmental functions and integrating them with the demands of multiple beneficiaries. Second, land use decision-making processes regarding secondary forests, which are increasingly cutting across multiple politico-administrative levels and bridging geographical spheres. At times when natural resource requirements and economic opportunities in neighboring countries are transformed into foreign policy parameters, transboundary aspects of natural resource management must be taken seriously into account. We therefore need a better understanding of decision-making processes in terms of scale and space, in order to implement realistic negotiation and planning mechanisms concerned with the future of secondary forests in the LMB.

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