A landscape mosaics approach for characterizing swidden systems from a REDD+ perspective

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Abstract

Swidden agriculture is often deemed responsible for deforestation and forest degradation in tropical regions, yet swidden landscapes are commonly not visible on land cover/use maps, making it difficult to prove this assertion. For a future REDD+ scheme, the correct identification of deforestation and forest degradation and linking these processes to land use is crucial. However, it is a key challenge to distinguish degradation and deforestation from temporal vegetation dynamics inherent to swiddening. In this article we present an approach for spatial delineation of swidden systems based on landscape mosaics. Furthermore we introduce a classification for change processes based on the change matrix of these landscape mosaics. Our approach is illustrated by a case study in Viengkham district in northern Laos. Over a 30-year time period the swidden landscapes have increased in extent and they have degraded, shifting from long crop-fallow cycles to short cycles. From 2007 to 2009 degradation within the swidden system accounted for half of all the landscape mosaics change processes. Pioneering shifting cultivation did not prevail. The landscape mosaics approach could be used in a swidden compatible monitoring, reporting and verification (MRV) system of a future REDD+ framework.

1 Introduction

Swidden cultivation, also called shifting cultivation or slash-and-burn, is a traditional agricultural practice in tropical forested landscapes. It is practiced in more than 40 countries around the world (Mertz, 2009) and is the dominant form of agriculture in many rural upland areas (Mertz et al., 2008; Raintree & Warner, 1986; Spencer, 1966). The alternation of cropping and fallow phases is the key characteristic of swidden systems, yet the dynamics of these systems are characterized by great variety, depending mainly on cultivation techniques, market opportunities and policies affecting forest and land uses (Nair, 1993; Sanchez, 1976; van Vliet et al., in press). Although the significance of swidden agriculture in the tropics is undisputable, there is a general lack of spatially explicit knowledge about the location and intensity of swidden cultivation, resulting in a general failure of land cover/land use maps to capture this practice from the global to the subnational scales (Padoch et al., 2007). There are two reasons for this.

First, historically swidden agriculture has had a bad reputation. It is still considered an archaic and underdeveloped form of land use (Mertz et al., 2009) and is blamed for many forms of environmental degradation (Fox, 2000; Fox et al., 2000; Padoch et al., 2007). Most prominently it is deemed responsible for tropical deforestation (Lawrence et al., 2010), vegetation degradation and fertility depletion (Arnason et al., 1982; Sanchez, 1976). In many tropical countries swidden agriculture is seen as a threat to forest landscapes (Keating, 1993) rather than being accepted as a traditional cropping system or as part of multifunctional landscape management (Ducourtieux et al., 2005; Finegan & Nasi, 2004; Lestrelin, 2010). Thus, its non-existence on maps is all the more welcome as policy makers have tried for decades to wipe it out of landscapes.

Second, swidden agriculture and the land use changes over time therein are difficult to delineate within a landscape (Padoch et al., 2007). Earth observation systems have greatly advanced in the last years and allow identification of different land cover types over large areas and at high resolution. Remote sensing has become an important tool for measuring LULCC over time and provides an effective and accurate evaluation of human impact on the environment (Bakr et al., 2010; Boyd, Foody, & Ripple, 2002; Lepers et al., 2005). Consequently a large body of literature has been devoted to the analysis of land use and land cover change (LULCC), particularly deforestation in tropical landscapes, using time series of satellite imagery. Indeed land cover data derived from satellite imagery already exist in many areas where shifting cultivation is the dominant form of land use. But swiddening as distinct land use category never appears in LULCC analyses because it is a complex system characterized by high spatial and temporal dynamics, which present significant challenges to the commonly used remote sensing techniques (Schmidt-Vogt et al., 2009; Sirén & Brondizio, 2009). Many studies bypass these methodological challenges and apply conventional methods of satellite image analysis in landscapes dominated by swidden agriculture to examine land cover change; e.g. Hartter et al. (2008) used Landsat TM data from 1988 to 2005 to develop a land cover classification and distinguish forest successional stages in milpa landscapes of the Yucatan peninsula. The authors used image subtraction to define pixel based trajectory classes (e.g. from Mid/late succession forest to crops) and to compared the percentage shares of these trajectories of change over time.Using similar methods Cabral et al. (2011) examined deforestation rates in miombo landscapes of Angola and Chowdhury (2006) analyzed deforestation rates and patterns in milpa landscapes in Mexico.

Notwithstanding the valuable contribution of these studies to the understanding of the dynamics of LULCC, the spatial delineation of swidden agriculture as a land use system and the different land use intensities therein require alternative methodologies that go beyond the common remote sensing approaches of pixel-based land cover analysis (Fox, 2000, Sirén & Brondizio, 2009). As a result of methodological gaps, areas under swidden are usually categorized as “Unstocked Forest”, “Unclassified” or even “Degraded Lands” on land cover maps (Padoch et al., 2007). To date studies addressing these gaps however have been rare. Yamamoto et al. (2009) developed an approach to delineate swidden landscapes in Northern Laos. They classified an eight year series of Landsat images into vegetated and bare areas. Using the created eight years land use history of every pixel different crop–fallow rotation cycles were identified. Using landscape mosaics Messerli et al (2009) developed an approach to distinguish swidden landscapes from other basic land use types at the national level based on official national land cover data of Laos.

Although largely uncharted and under strong policy pressure to disappear from countries’ landscapes, swidden systems have now, however suddenly appeared on the negotiating table as a result of the new global agenda for climate change mitigation. To date, emission reductions from land use change and forestry have not yet been included as a category in the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. They were, however, formally included in the post-2012 international climate regime through the proposed REDD+ mechanism for “Reduced Emissions from Deforestation and Degradation and Enhancement of Carbon Stocks” (REDD+) (COP16, 2010). Tropical deforestation caused close to 20% of global anthropogenic CO_2 emissions in the 1990s (IPCC, 2007) and 12% in 2008 (Le Quere et al., 2009). Across the tropics more than 55% of new agricultural land was created at the expense of intact forests, and another 28% came from disturbed forests between 1980 and 2000 (Gibbs et al., 2010). Driven by the negative perception that swidden degrades vegetation and contributes to deforestation, swidden agriculture is explicitly listed today as a main cause of the emissions related to this form of land cover change by many tropical countries (Griffiths, 2008). Consequently, swidden landscapes have become a central focus of actions against climate change. REDD+ actions planned for swidden landscapes usually follow either one of two opposed lines of thought. First, the common belief attached to swiddening provides an argument to further promote the demise of swidden within the realm of REDD+ (Angelsen, 2008). Accordingly, it is proposed that REDD+ payments could be used as supplementary financial incentives for national development programs and forest policies which aim to eradicate swidden farming systems through transformation into settled agriculture or other types of intensive land use (Angelsen, 2008; Dooley et al., 2008). In the second line of thought, the argumentation is based on the perception of swidden as a traditional form of agriculture, which harbors rich biodiversity (Rerkasem et al., 2009) and provides food diversity for local communities (Colfer, 2004). Therefore REDD+ should focus on strengthening and giving new values to these systems. Financing from REDD+ could be used for a reversion to longer crop-fallow periods, raising the carbon stocks at landscape level, and in addition enhancing landscape multifunctionality (Mertz, 2009). The latter argument is now accepted by the scientific community, but it has so far not found its way into policy and decision making (Van Noordwijk et al., 2008). As a consequence of these two opposed lines of thought, there is a heated debate on whether swidden areas and poor swiddening farmers will really benefit from REDD+ or whether the mechanism will not rather cause more harm to the system and people’s livelihoods therein (Peskett et al., 2008).

Swidden systems are thus at a crossroads: policies may either aim at their continued elimination or hail them as contributing to multifunctional and sustainable land use systems. Therefore, it is crucial to be able to delineate and classify swidden systems adequately. So far the common categories of land cover/land use serving as a basis for assessing deforestation and degradation have led to defective analysis of swidden and lack of understanding of the contribution of swidden to these change processes (Griffiths, 2008). As long as these features remain unknown, REDD+ discussions about swidden and potential future REDD+ actions will lack sound grounding in scientific evidence and therefore risk being inappropriate and poorly located. Evidence-based land use planning and decision making therefore urgently require consideration of the spatial features of swidden agriculture at a landscape scale – both in terms of the extent and intensity of swidden.

In this article we address the challenge of spatial delineation of swidden systems at the sub-national level. Indeed, this is the level where land use planning in general, and planning for the implementation of REDD+ projects in particular, commonly takes place. While land cover data created with common methods of remote sensing and geographical information systems (GIS) frequently exist, we propose an approach for identifying and characterizing swidden areas using such existing land cover data. Based on this approach we develop a classification of change processes, such as deforestation and vegetation degradation that takes due account of the complex landscapes caused by swidden agriculture systems. We illustrate our approach with an example from a region representative of traditional swidden landscapes in the northern uplands of Laos. Finally, we discuss the results of our landscape mosaic classification within the context of REDD+ initiatives in Laos.

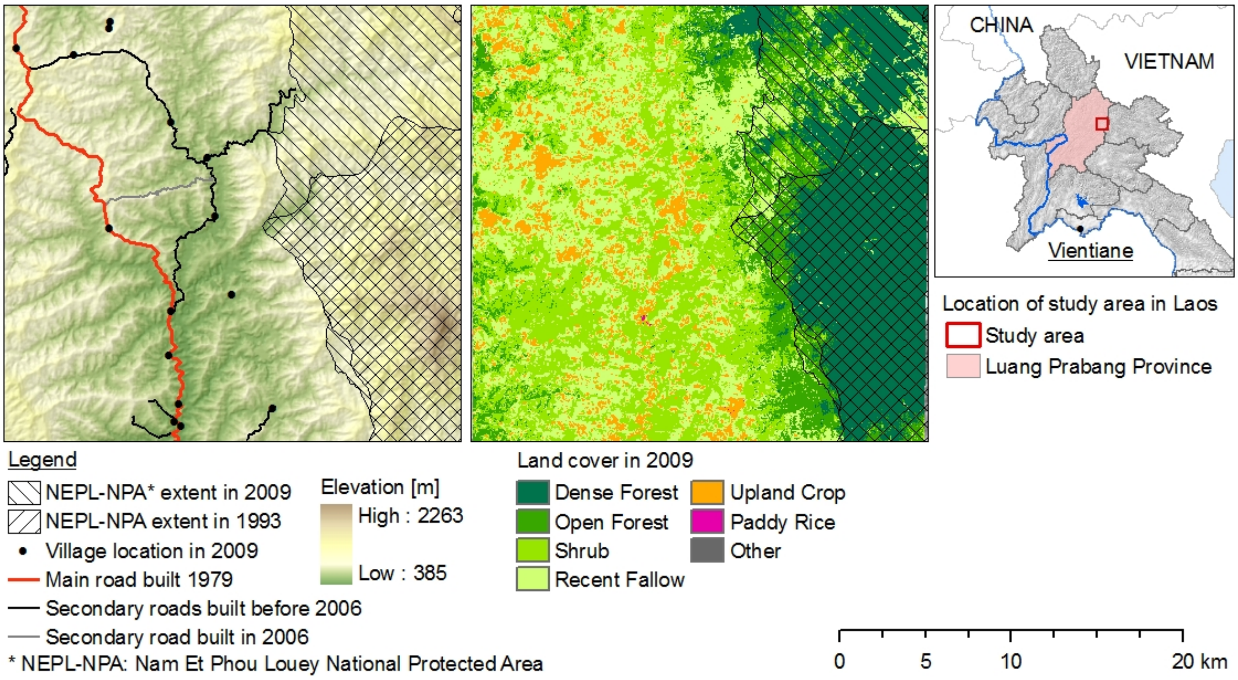
2 Material and methods

2.1 Study area and basic land cover data

The study site used to illustrate our approach is located in Viengkham District, Luang Prabang Province (figure 1). Characterized by mountainous terrain and narrow river valleys, this region is typical of the northern uplands of Laos. In Viengkham District, swidden agriculture is by far the dominant land use system. Permanent agriculture is hardly present and is limited to small areas of paddy in the valley bottoms (Castella et al., 2011).

Two distinct features characterize our 26km x 26km study area. First, the road network, which comprises the main road, built in 1979, crossing through from the northwestern corner down to the southern edge, and a more recent secondary road network built in 2006 in the central part. Second, the Nam Et Phou Louey National Protected Area (NEPL-NPA); this protected area is an important site for biodiversity conservation. Areas of natural forests were lost because of swidden agriculture, logging for timber and firewood collection within the protected area, and this unregulated over-harvesting of animals and plants for trade and subsistence has been the main threat to the flora and fauna of the NEPL-NPA (Johnson, in press). The NEPL-NPA was established in 1993; it covers 422,900 ha and has been under active management since 2000. In 2008 park specific regulations were endorsed at provincial and district levels to prevent forest and wildlife crime and promote sustainable land use and biodiversity conservation. As shown in figure 1, the park area covered the south-eastern part of the study area in 1993 and was expanded towards the north in 2008 to cover a total area of 595,000 ha (Johnson, in press).

Figure 1: Overview of the study area in Viengkham District, Luang Prabang Province



The published land cover data used as basic data for developing the approach presented in this paper were created based on Landsat imagery using supervised classification and visual image interpretation (Kongay et al., 2010). The land cover classes include: 'Dense Forest' – natural undisturbed forest; 'Open Forest' – degraded primary forest due to timber extraction or regenerating after cultivation; 'Shrub' – shifting cultivation fallow areas older than three years and up to 10 to 15 years; 'Recent Fallow'– shifting cultivation fallow areas of up to three years of age; 'Upland Crop' – areas currently under cultivation; and finally 'Paddy Rice', 'Residential Areas' and 'Clouds'. Figure 1 shows the land cover data for the year 2009.

2.2 Challenges for approaches delineating swidden landscapes

Swidden systems are characterized by high spatiotemporal dynamics (Sirén & Brondizio, 2009). A plot is cultivated for a short period of one to three years and afterwards left fallow for several years so that the vegetation and soil fertility can regenerate. Such a plot is then prepared for another cultivation cycle by slashing and burning the fallow vegetation (Nair, 1993; Roder, 2001). This temporal variation of land cover of one pixel leads to a fragmented landscape consisting of patches of fields currently cultivated in a matrix of fallows with different regrowth stages (Tottrup et al., 2007). Swidden does not only leave a characteristic temporal footprint in the landscape, but it also forms a characteristic spatial pattern. The locations of the cultivated plots and the different fallow categories are not stable over time, but move around within the area under swidden from one year to the next. These spatial dynamics make it challenging to distinguish between swidden and other land uses/covers, e.g. permanent agriculture or natural vegetation, as there are no clear boundaries. One way of delineating swidden would be to produce binary images (cultivated or non-cultivated) over consecutive years and then define swidden as the area of inclusive disjunction of pixels marked as cultivated. However this would make it impossible to assess deforestation and degradation in swidden landscapes, as the sole identification of the areas under swidden would already rely on a long time series of data.

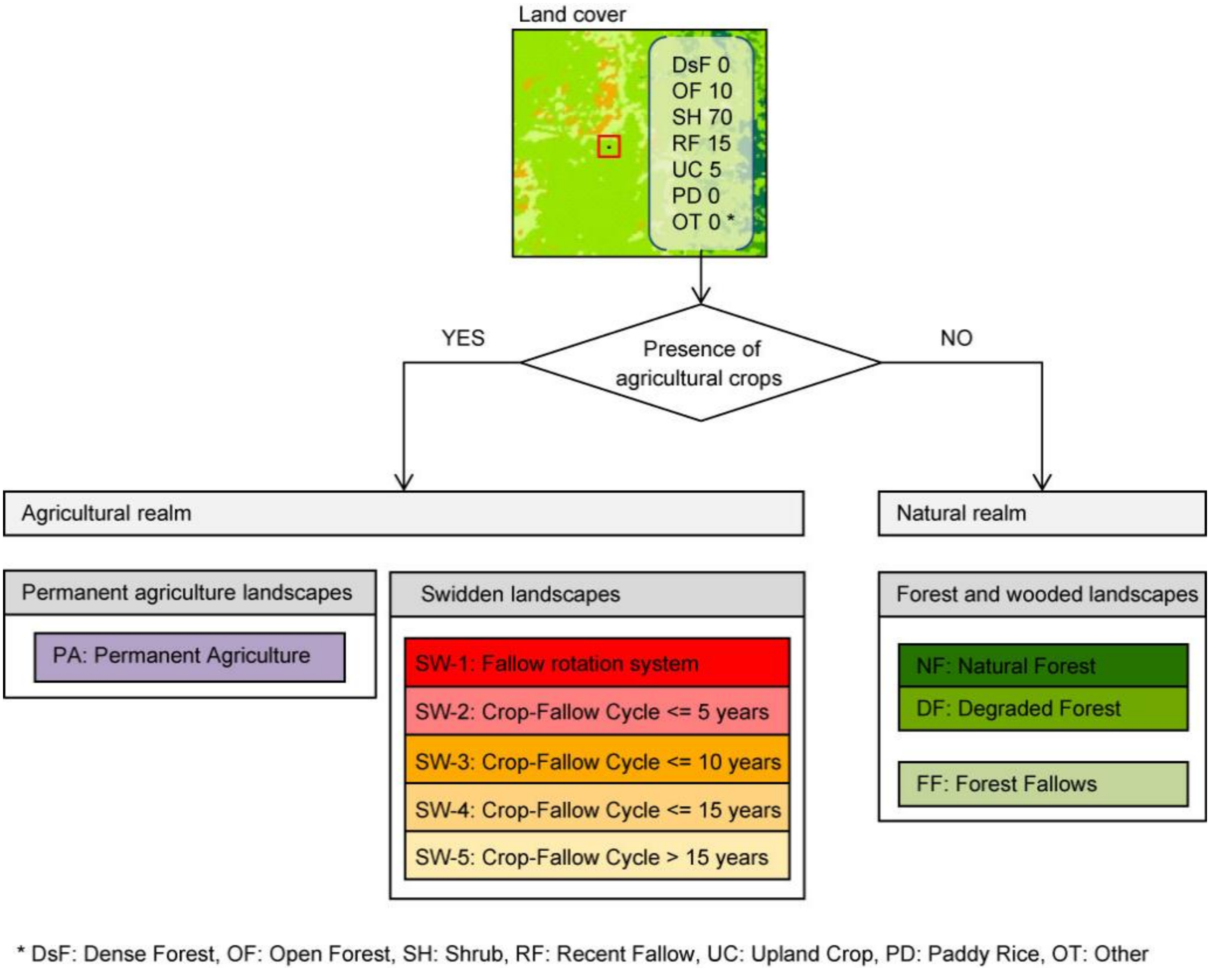
Consequently, there is a trade-off between assessing the extent of swidden areas and land use change processes prone to pixel based approaches. We therefore developed an alternative approach based on landscape mosaics. The basic idea is that while the land cover types of the single pixels change constantly from one year to the next, the overall composition of a landscape remains the same in a stable swidden system. Hence, we focused on the patterns that are created from the different land cover types and the way the patterns are repeated in similar combinations over larger areas. These properties are more insightful for characterizing a landscape (Forman & Godron, 1986; Noss, 1990), particularly swidden landscapes, and make it possible to move away from the focus on the land cover and temporal dynamics of each single pixel.

2.3 Identifying and characterizing swidden systems using landscape mosaics

In order to derive landscape mosaics from the basic land cover provided for our study area, we followed the general steps introduced by Messerli et al (2009). We first analyzed spatial patterns of the original land cover data, without interpreting them topically. For every pixel we found out by what type of land cover it was surrounded. Using a moving window technique we computed the share of each land cover class in the neighborhood of each pixel and attributed this information to the pixel. “Neighborhood” was defined through the choice of the window size. Based on previous studies on the relation of accessibility and land cover change in Laos a 2km window size was used (Heinimann, 2006). The information gained was stored in a 7-dimensional vector for every pixel, replacing the original land cover information.

In a second step we interpreted the spatial patterns of land cover data with a view to extracting information on land use (Messerli et al., 2009). In other words we stipulated that by understanding the patterns in which land cover patches co-exist we could draw conclusions on the type and intensity of swidden agriculture. For this purpose we developed a hierarchical decision tree, as shown in figure 2. First, we distinguished between the two broad realms of natural vegetation and agricultural areas. We distinguished the *Natural realm* on the basis that there are no clearly visible indications of human activities (FAO, 2000). We thus categorized pixels without a presence of either ‘Upland Crop’ or ‘Paddy Rice’ in their land cover vector as belonging to *Natural realm*. Given the absence of other natural landscape elements (e.g. ‘Water’ or ‘Rock’) in our basic land cover data, *Natural realm* contained only *Forest and wooded landscapes*. Within this landscape type we differentiated between three landscape mosaics based on the presence and the macro-pattern of the land cover types. Continuous forest cover, defined as more than 80 percent (Di Gregorio, 2005), and domination of the land cover class ‘Dense Forest’ was classified as “Natural Forest”[NF] mosaic, whereas domination of the land cover ‘Open Forest’ was classified as “Degraded Forest” [DF] mosaic. Finally, the landscape mosaic “Forest Fallows” [FF] existed if fragmented forest of less than 80 percent cover was found and the rest of the area was covered by fallow regrowth vegetation, given by ‘Shrub’ and ‘Recent Fallow’ land cover classes. The “Forest Fallows”-mosaic thus describes areas that were previously under use by swidden agriculture, but that are not cultivated at the given time.

Figure 2: Approach for the delineation of landscape mosaics as new spatial units



Within the *Agricultural realm* we distinguished between *Permanent agriculture landscapes* and *Swidden landscapes*, and within *Swidden landscapes* between different land use intensities based on Ruthenberg's R-value (Ruthenberg, 1976). In the spatial dimension the R-value is calculated by dividing the cultivated area by the total usable area (Nair, 1993; Raufu, 2010; Ruthenberg, 1976; Van Noordwijk, 1999). The mosaic "Permanent Agriculture" was defined by R > 0.67. As can be seen in figure 2, we distinguished five different classes of use intensity within the *Swidden landscapes* following a gradient from mosaic SW-1, which describes the most intensive land use form with fallow rotation (R <= 0.67), to the mosaic SW-5, with least intensive land use and a crop-fallow cycle longer than 15 years (R <= 0.067).

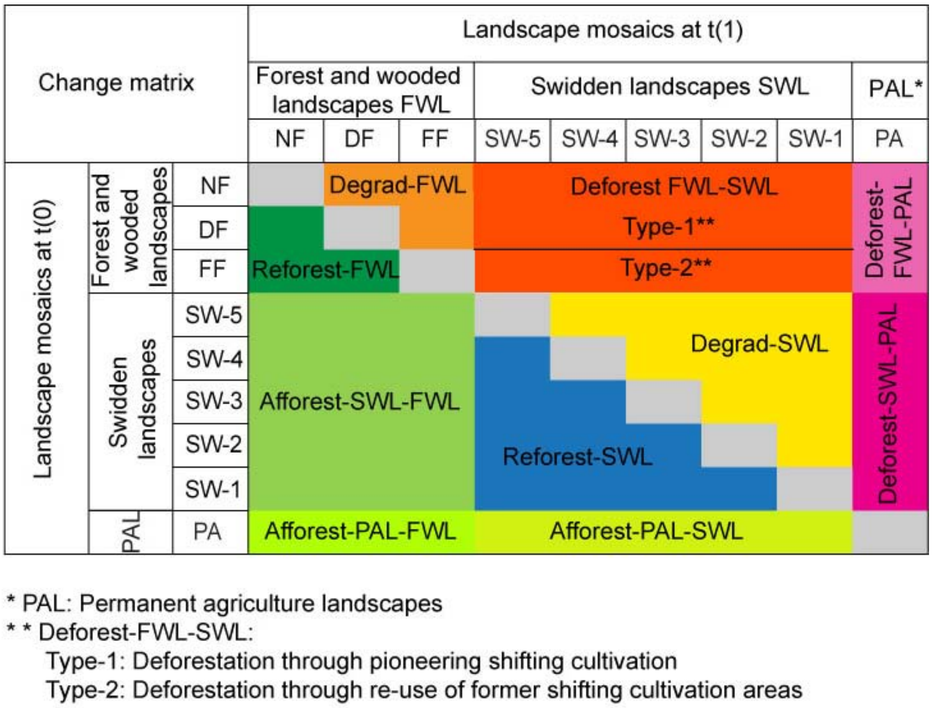
2.4 Classification of change processes using landscape mosaics

As mentioned above, swidden agriculture leaves a characteristic temporal footprint in the landscape causing difficulties when studying change processes on a pixel basis: What does it mean when a pixel changes from shrub to cultivated field? Using a common land cover change approach one would classify it deforestation. However within a swidden system this sequence of land cover classes shows an excerpt of the system inherent cycle of vegetation clearance and regrowth. Classifying it as deforestation would be misleading. With the landscape mosaics approach, however, the perspective changes from pixels of land cover to landscape mosaics that imply land use. Our approach allows us to distinguishing patterns resulting from how humans interact with and manage complex landscapes (Lambin & Geist, 2006; Messerli et al., 2009). For the assessment of landscape change processes we therefore constructed a change matrix based on the landscape mosaics data of two points in time. The resulting types of change categories are represented in figure 3.

Changes from one landscape type to another causing forest loss were classified as a type of deforestation. Particularly a change from *Forest and wooded landscapes* to *Swidden landscapes* was called Deforest-FWL-SWL (see figure 3), a change from *Forest and wooded landscapes* to *Permanent agriculture landscapes* was called Deforest-FWL-PAL, and a change from *Swidden landscapes* to *Permanent agriculture landscapes* was called Deforest-SWL-PAL. Generally, these changes not only imply loss in forest areas but they denote changes of the land use practices.

A decrease of forested areas within any of the three landscape types was classified as degradation. As shown in figure 3 Degrad-SWL specified loss of forest cover within *Swidden landscapes*. It describes an intensification of lands use practices which results from shortening of the crop-fallow cycle length and causes a switch between swidden mosaics. The increased extraction of forest products within the *Forest and wooded landscapes* which can trigger e.g. change from the “Natural Forest” (NF) mosaic to the “Degraded Forest” (DF) mosaic was called Degrad-FWL.

Figure 3: Characterization of change processes based on the change matrix of landscape mosaics (abbreviations for landscape mosaics: see figure 2)



The landscape mosaics changes which increased the forested areas were classified as follows: We defined changes in-between landscape types as afforestation as these changes specify an increase in forest areas which goes along with a change in land use. For example, Afforest-SWL-FWL specifies a temporal or permanent abandonment of swidden agriculture, and causes change from a mosaic of the *Swidden landscapes* to a mosaic of the *Forest and wooded landscapes*.

Finally, regeneration processes within one of the three landscape types was classified as reforestation. Hence Reforest-SWL in figure 3 describes a change in swidden practice from one swidden mosaic to another swidden mosaic with longer crop-fallow cycle. Reforest-FWL specifies the reduced extraction of forest product within the *Forest and wooded landscapes* and implies a regeneration of the land.

3 Results

3.1 Identifying and characterizing swidden systems with the landscape mosaics approach

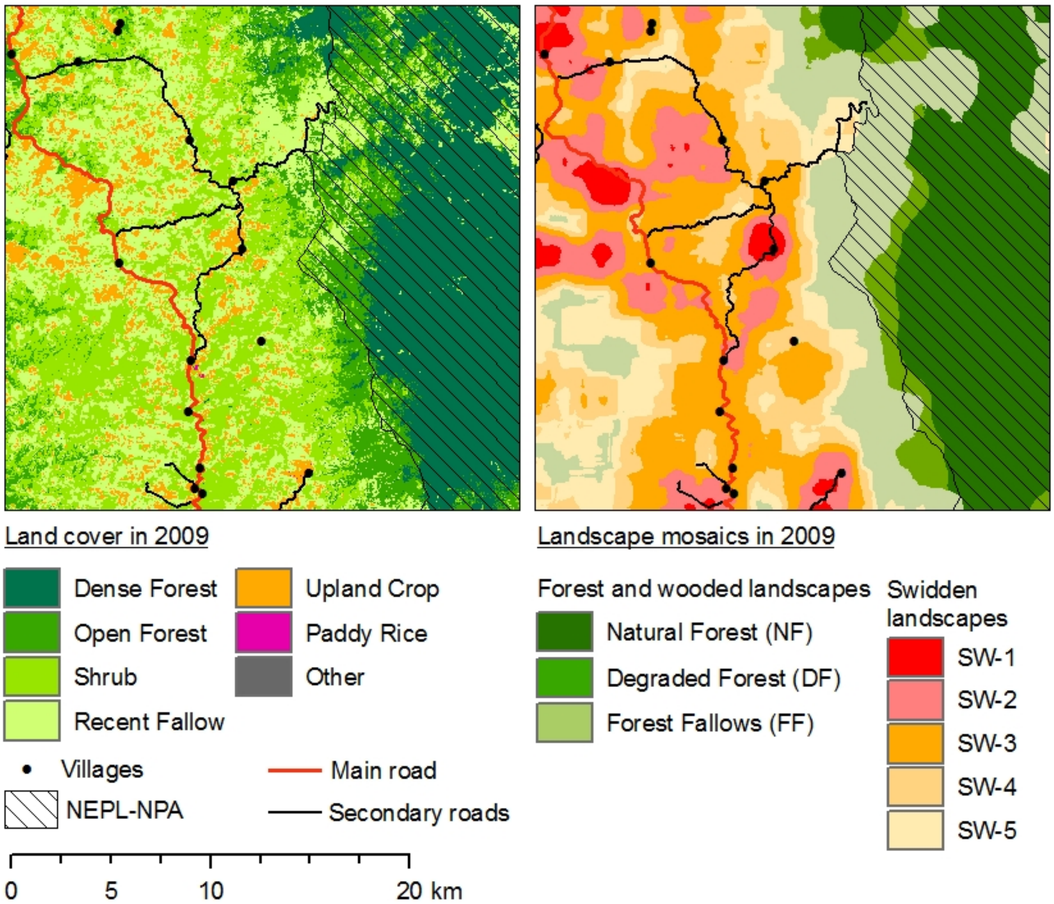
We tested the landscape mosaics approach using land cover data from 2009. As shown in table 1 the original land cover data for the year 2009 was dominated by 'Recent Fallow' and 'Shrub'. These categories made up for 29% and 26% cover, respectively. Areas cultivated in 2009, i.e. the land cover class 'Upland Crop' and 'Paddy Rice', accounted for only 7.4% of the territory. Using the landscape mosaics approach we achieved a more differentiated perspective on the land use within the study area, which adequately accounts for the category of "Swidden" and its dynamics within the study area. It revealed that a total of 55% of the study area was under swidden cultivation, while the rest of the study area (45%) had a natural character, and was included in the *Forest and wooded landscapes*. *Permanent agriculture landscapes* did not exist in 2009.

Table 1: Percentage shares of land cover classes compared to landscape mosaic classes in the study area for the year 2009

Land cover 2009			**Landscape mosaics 2009**		
Land Cover	**Percent cover**		**Mosaic**	**Percent cover**	**Percent cover within landscape types**
Dense Forest	24.0		Natural Forest	23.6	52.6
Open Forest	13.7		Degraded Forest	4.0	8.8
Shrub	25.9		Spared Land	17.3	38.5
Recent Fallow	28.9		SW-5: Crop-Fallow-Cycle > 15 years	9.9	18.0
Upland Crop	7.4		SW-4: Crop-Fallow-Cycle <= 15 years	12.8	23.3
Paddy Rice	0.0		SW-3: Crop-Fallow-Cycle <= 10 years	20.3	36.9
Other land cover	0.0		SW-2: Crop-Fallow-Cycle <= 5 years	9.7	17.6
			SW-1: Fallow rotation system	2.3	4.2

Figure 4 shows the initial land cover map and the resulting landscape mosaics map which we created. It reveals that *Swidden landscapes* covered the western part of the study area. Herein, a clear gradient of use intensities was identified, with mosaics of high use intensities [SW-2] and [SW-3] along the road network and in the vicinity of villages. Ring shape patterns of increased swidden intensities were found around village settlements, which is consistent with ground observations (Castella et al., 2011; Kongay et al., 2010). Areas of low swidden intensity were found in more remote and inaccessible areas in the southwest and towards the protected area. Overall, crop-fallow cycles of 5 to 10 years dominated, accounting for one third of the area under swidden. Long crop-fallow cycles – [SW-4] and [SW-5] – together accounted for another 41% of the area under swidden, and crop-fallow cycles shorter than five years made up 22% of the area under swidden cultivation, which is less than 12% of the total area.

Figure 4: From land cover to landscape mosaics: the Viengkham study area in 2009 using the original land cover data (left) and the landscape mosaics approach (right)



The “Natural Forest” [NF] mosaic dominated with more than half (53%) of the cover of *Forest and wooded landscapes*, which is equivalent to 23.6% cover of the total area. This is the same proportion of land which was previously classified under the land cover class ‘Dense Forest’. This means that the vast majority of all pixels originally classified as ‘Dense Forest’ was located next to one another and formed large forest patches. Otherwise these pixels would have been distributed among other mosaics.

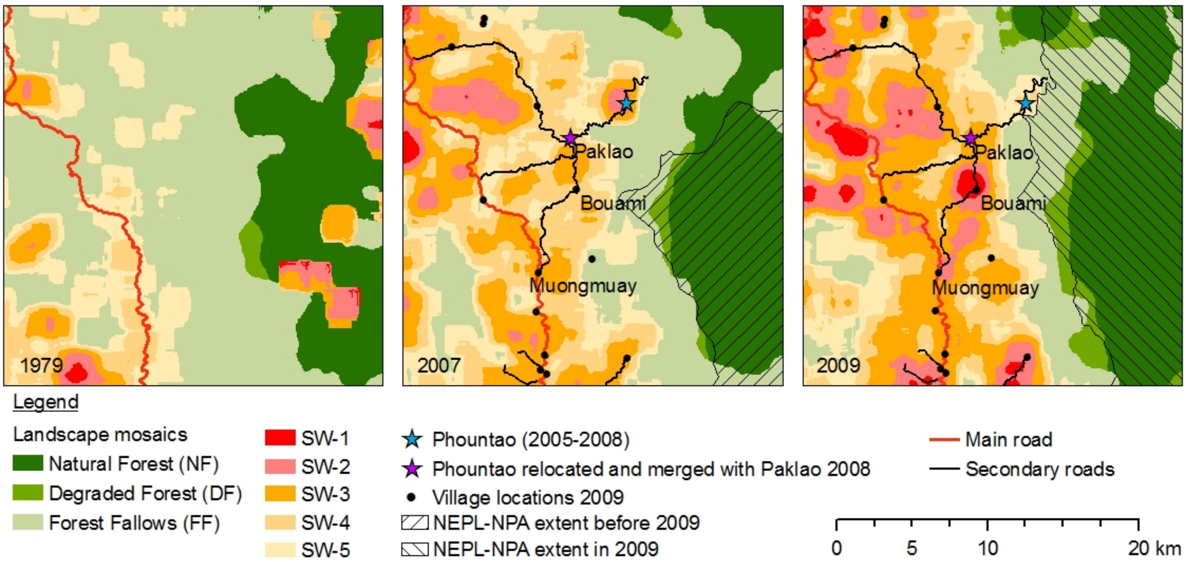
The [NF] mosaic was located almost entirely within the boundaries of the protected area. In contrast the "Degraded Forest" [DF] mosaic accounted for only 4% of the territory, which is much less than expected looking at the share of the original land cover class "Open Forest", commonly equated with degraded forest. This shows that the pixels classified as 'Open Forest' were much more fragmented and mixed within a matrix of other land cover classes and thus were not the main defining cover for the resulting landscape mosaic.

Finally the "Forest Fallows" [FF] mosaic was found as a broad strip along the border of the NEPL-NPA. This region of our study area is known to have been abandoned by swiddeners as a consequence of the law enforcement activities in the protected area, which include strict prohibition of swidden in a buffer zone around the NEPL-NPA.

3.2 Detection and quantification of landscape changes in the study area

In order to examine long-term and short-term landscape changes in our study area we generated landscape mosaic maps for 1979 and 2007, and compared them with the 2009 map. Figure 5 shows the maps for these three points in time; changes are discussed in detail in the following sections.

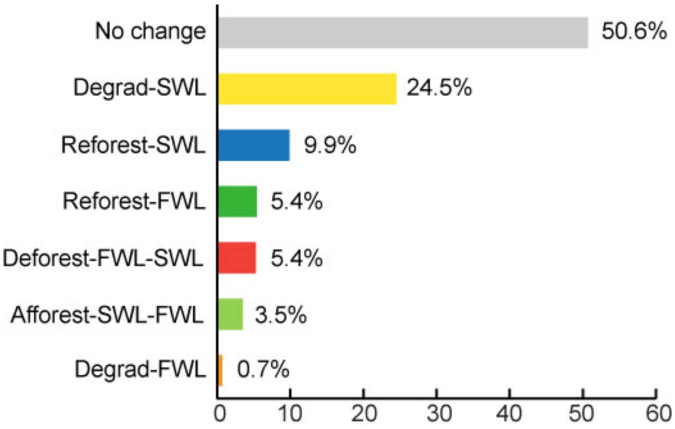
Figure 5: Landscape mosaics maps for 1979, 2007 and 2009 for the study area



3.2.1 Short term changes from 2007 to 2009

In the period from 2007 to 2009 the overall intensification of the swidden areas strikes the eye (figure 5) as a consequence of the expansion of the swidden mosaic with highest intensity [SW-1] and [SW-2]. To quantitatively assess the changes from 2007 to 2009 we calculated the landscape mosaics change matrix as introduced in figure 3. This change matrix (see figure 7)revealed that the overall partition of the study area into *Swidden landscapes* and *Forest and wooded landscapes* remained more or less the same: in 2007 *Swidden landscapes* occupied 53% and *Forest and wooded landscapes* made up the remaining 47% of the area, while the shares where 55%, respectively 45% in 2009. Permanent agriculture was absent both in 2007 and in 2009. The aggregation of the numbers in the change matrix into the main mosaics change processes is given in figure 6. It showed that half of the study area (precisely 49.4%) was subject to landscape mosaic change. In fact, most changes took place within the *Swidden landscapes.*

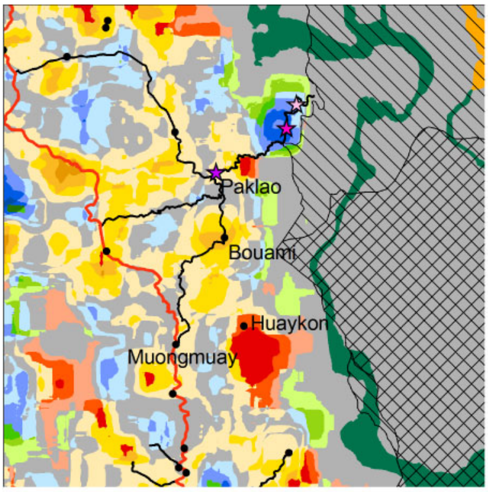
Figure 6: Shares of change processes in the study area from 2007 to 2009



Intensification within the *Swidden landscapes*, termed Degrad-SWL in figures 3 and 6, constituted the largest share of all occurring changes, amounting to half of them (or 24.5% of the overall changes). This confirms the results obtained through field surveys in the study area (Castella et al., 2011), and provides quantitative evidence of the intensification of the swidden system from 2007 to 2009. Degrad-SWL was found along the roads and in the vicinity of villages. However, alongside these degradation processes within the *Swidden landscapes*, we also observed a positive change from short to longer crop-fallow cycles: Reforest-SWL was the second largest change class. It accounted for about 9.9% of all changes and occurred predominantly in remote parts of the study area.

The analysis of the change matrix revealed that 65% of the area under swidden underwent either degradation or reforestation processes. The map in Figure 7 visualizes the spatial pattern of the changes occurring from 2007 to 2009. The different change processes are given in distinct colors following in line with figure 3 an6. The intensities of change within these change categories are shown through color gradients. The maps shows that the mosaics changes were of gradual character: most frequently they happened from one mosaic to the following with either more intensive or less intensive use. Abrupt changes, e.g. intensification from [SW-5] to [SW-2], were uncommon.

Figure 7: Landscape mosaics changes and change intensities from 2007 to 2009



Map legend and change matrix with mosaics changes in percent of total

		Forest and wooded landscapes FWL			Swidden landscapes SWL					PAL
		NF	DF	FF	SW-5	SW-4	SW-3	SW-2	SW-1	PA
Forest and wooded landscapes	NF	21.1	0.0	0.7	0.0	0.0	0.0	0.0	0.0	Did not exist
	DF	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	
	FF	2.6	2.8	13.1	2.4	1.6	1.3	0.1	0.0	
Swidden landscapes	SW-5	0.0	0.0	2.2	2.7	3.2	3.8	1.0	0.3	
	SW-4	0.0	0.0	0.9	2.9	4.9	7.3	2.4	0.7	
	SW-3	0.0	0.0	0.4	1.6	2.4	6.3	4.5	1.0	
	SW-2	0.0	0.0	0.0	0.4	0.4	1.4	1.3	0.2	
	SW-1	0.0	0.0	0.0	0.1	0.3	0.3	0.2	0.0	
PAL	PA	Did not exist								

The consequences of the expansion of the NEPL-NPA can be well observed in the landscape mosaics change map in figure 7. Phountao village was moved away from the NEPL-NPA boundary to the nearest village settlement of Paklao; after it had already been moved in 2005 by a shorter distance (see successive locations of the village in figure 7). This village relocation in 2008 led to an abandonment of agricultural activities appearing as afforestation (light green in figure 7) in the distant radius of the old village locations of Phountao. In addition it led to adoption of longer crop-fallow cycles in the near radius of the old village locations, which appeared as Reforest-SWL of uncommonly high change intensity over three mosaics, namely from [SW-2] to [SW-5] (dark blue in figure 7). A small patch of deforestation was found in the vicinity of Paklao. Natural population increase – well distributed across the villages (Castella et al., 2011) – is not, in itself, a sufficient cause to explain such major spatial changes in land use intensity over a short time period. We interpret this deforestation as a result of the displacement of the village of Phountao, reducing the pressure on land within and near the NEPL-NPA, but moving it to the surroundings of Paklao.

Contrary to the high dynamics in *Swidden landscapes*, the mosaics within the *Forest and wooded landscapes* were largely stable. From 2007 to 2009 there was hardly any increase of use within the forest areas; degradation within the *Forest and wooded landscapes* (Degrad-FWL) was only 0.7%. But there was an increase in the “Degraded Forest” [DF] mosaic at the expense of the “Forest Fallows” [FF] mosaic. This reforestation (Reforest-FWL) amounted to 5.4% of all changes (see figure 6) and is prominently visible on the map in figure 7 as a long thin band following in large parts the boundary of the protected area. It was caused by abandoned swidden areas which regenerated back to a more natural forest environment. We interpret this as another consequence of strict management in the NEPL-NPA.

Our change analysis showed that from 2007 to 2009, 5.4% of the area was subject to deforestation – specifically change from *Forest and wooded landscapes* to *Swidden landscapes* (see Deforest -FWL-SWL in figure 6). The change matrix revealed that these deforestation processes originated only from the mosaic "Forest Fallows" [FF], and a large patch of this type of deforestation was found south of the village of Huaykon (figure 7). None of this deforestation originated from "Natural Forest" [NF] or from "Degraded Forest" [DF], it affected only areas which were already used for swidden agriculture before but had been left uncultivated in the past (in 2007). In 2009 these areas located further away from the buffer zone of the NPA were cultivated again while the areas closer to the NPA were regenerating (see green Afforest-SWL-FWL zones located East of Huaykon village settlement in figure 7). There was no pioneering shifting cultivation happening from 2007 to 2009 in the study area.

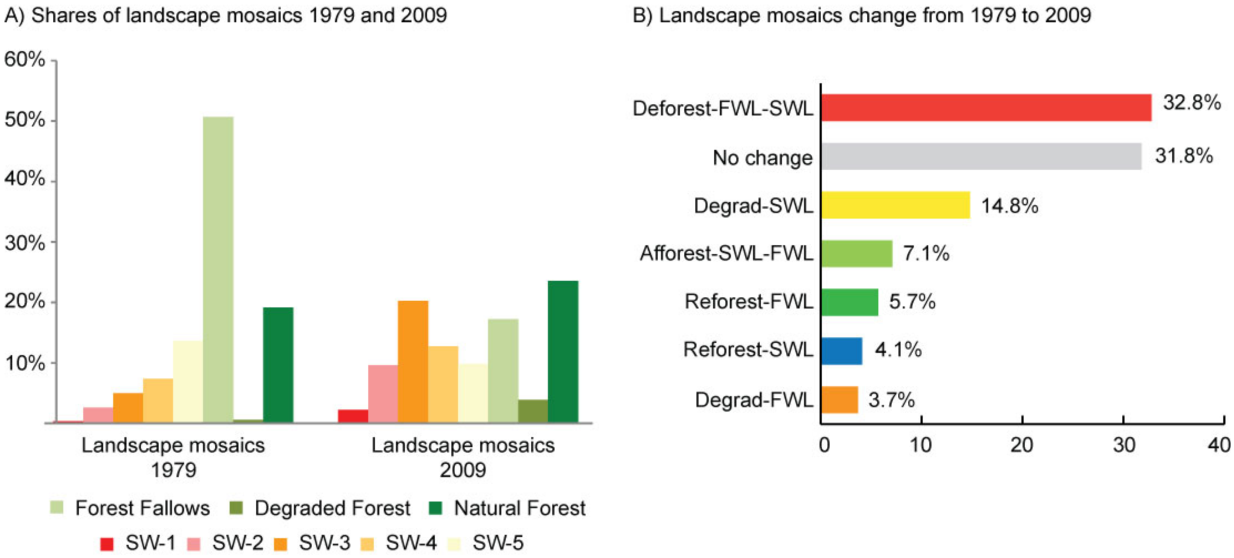
The intensification of crop-fallow cycles around the village of Bouami, as well as in patches along the road between Paklao and Bouami, was higher than the average intensification seen throughout the *Swidden landscape*, namely from [SW-4] or [SW-3] to [SW-1] around Bouami, and from [SW-4] to [SW-2] along the road. Again, this could be attributed to the relocation of Phountao village; another driver behind this rapid intensification was also the opening of the dust road from Muongmuay to Bouami and Paklao in 2006.

3.2.2 Long-term changes in the study area

Using the landscape mosaics change approach we analyzed a 30-year time period, from 1979 to 2009, as an example of how to assess historical forest degradation and deforestation. The analysis revealed that the distribution into S*widden landscapes* in the east and *Forest and wooded landscapes* in the west already existed thirty years ago. However the borders of these two landscape types were not so clear in 1979. The highest intensities of swidden agriculture were in fact located within regions which are today part of the NEPL-NPA (see figure 5). However, these areas located within today's NPA totally disappeared in 2009 and regenerated into secondary forests. As shown in figure 5, the area under swidden was quite a bit more homogenous and dominated by long crop-fallow cycles. The map shows that only some islands of higher change intensity were present. Intensive swidden areas [SW-1] and [SW-2] mosaics were found in the southwestern part around the former district administrative center, which has since then been relocated outside the study area.

Over the past 30 years the *Swidden landscapes* increased a great deal, from 29% in 1979 to 55% in 2009 (figure 8). Deforestation (Deforest-FWL-SWL) was the major landscape mosaics change process. However, a closed look at the change matrix revealed that even in this long time period there was no conversion from the [NF] mosaic and [DF] mosaic into any swidden mosaics. Therefore there was no pioneering shifting cultivation. Again deforestation was limited to re-using areas of "Forest Fallows" that were not used in 1979 but had been used before that point in time. In addition to this deforestation, there was intensification within the existing areas under swidden; half of the swidden areas of 1979 were cultivated at shorter crop-fallow cycles in 2009. This general shortening of the fallow period over the last 30 years detected by the landscape mosaics approach also supports the findings of previous local case studies reporting decrease in crop-fallow cycles in northern Laos (e.g. Rasul & Thapa, 2003; Roder, 2001; Thongmanivong & Fujita, 2006), thus validating our approach.

Figure 8: Shares of landscape mosaics in 1979 and 2009 and observed change processes in the Viengkham study area



4 Discussion

The landscape mosaics approach for spatial identification and characterization of swidden agricultural landscapes is innovative in two respects. First, from a methodological viewpoint, the approach offers a new way of locating swidden agriculture and understanding its dynamics, based on existing land cover data. Such land cover data is usually generated by visual interpretation of satellite imagery – a method which is cheap and straightforward and is often readily available. However it is often disregarded for landscape-level analyses of deforestation and forest degradation. This is due not only to the lack of contextual information provided, as discussed above, but also to the fact that man-machine interactive visual interpretation often renders poor classification accuracy. The landscape mosaics approach creates generalized land use types (landscape mosaics) based on the information from a set of pixels from a whole area (or window), using the principle of vicinity. The pattern analysis applied as the first step in our approach leads to an overall fuzzification of the original land cover data. While precision concerning the exact land cover type of each single pixel is lost, some of the errors and uncertainties inherent in the underlying land cover data are leveled out, as the land cover type of one single pixel loses in significance. Knowledge is gained on the kind of landscape type (*Swidden landscapes* or *Forest and wooded landscapes*) a pixel is located in based on the land cover types of its neighbors. Our mosaic approach therefore adds value to existing land cover data sets in terms of understanding land use and can thus facilitate land use planning at subnational levels.

Second, from a topical viewpoint, the landscape mosaics change matrix enables a classification of forest degradation and deforestation that makes a significant contribution to the ongoing REDD+ debate concerning swidden agricultural systems. The uplands of northern Laos are commonly described as places of high land use dynamics (Roder, 2001; Thongmanivong & Fujita, 2006). Our landscape mosaics change analysis revealed that our study area is no exception, as large shares of the study area were subject to change, over shorter and longer time periods. However, from 2007 to 2009 the vast majority of all changes took place within the swidden agriculture system, which means that the main processes fall into the category of forest degradation. Over the past 30 years, deforestation was the main change process. Nonetheless, we found that none of this deforestation was due to pioneering shifting cultivation: instead, old swidden areas were reintegrated into the swidden system.

The landscape mosaics change analysis can lead to new recommendations for REDD+ actions: taking the two years 2007 and 2009 as the historical baseline in the Viengkham study area, it would be possible to recommend that REDD+ actions should consider the effects of previous interventions that led to reforestation around the protected area, as well as the shortening of crop-fallow cycles in *Swidden landscapes*. More carbon could be sequestered into the landscape by reverting back to longer fallow cycles (Mertz, 2009). A core question would be, from an emission reduction perspective, to find out whether gains through extensification and reforestation exceed the losses linked to degradation associated to swidden intensification processes.

The REDD+ debate heavily circles around concerns of ‘additionality’ and ‘leakage’ (Angelsen, 2008; Baker et al., 2010) that we can take up here based on our landscape mosaics approach. ‘Additionality’ means the reduction of emissions by sources or the enhancement of removals by sinks that are additional to what would occur in the absence of a REDD+ activity (Angelsen, 2008). In the early 1990s, the Lao government launched a nationwide Land Use Planning and Land Allocation program with the aim to foster socio-economic development while at the same time protecting the environment (Lestrelin et al., 2011). Since then, development projects and government policies have heavily influenced the development of and change in land use in the northern uplands of Laos. Against this background, important questions arise with regard to setting a reference trend for REDD (Angelsen, 2008). Should these interventions be considered as “pre-REDD” activities or as “business as usual”? Any current project that slows down forest degradation, stops it, or turns it into reforestation, should be regarded as fulfilling the additionality criterion. A map showing the location of degradation and reforestation within the swidden system as given in figure 7 can assist in discussing and defining the right locations for supporting current or initiating new REDD+ interventions.

‘Leakage’ means that emissions are displaced from within a project area to areas outside the project area (Angelsen, 2008; Mollicone et al., 2007). ‘Leakage’ is closely coupled with liability for forest degradation and deforestation, and REDD+ benefit sharing (Mollicone et al., 2007). The main instrument of forest conservation in our study site has been to move local populations away from protected areas or confining them in very limited areas through restrictive land use planning. Considering it as a “project” which also targets zones surrounding the protected area, one observes a significant ‘leakage effect’ from the NPA borders to agricultural village lands. The landscape mosaics approach helps detect this spatial shift by displaying changes in the intensity of swiddening. In the name of forest protection, the regenerating forest cover was excluded from village land and put under state tenure and management. Forest tenure shifted away from the communities to the state, leaving potential REDD+ benefits to the state while local communities may not be rewarded for their forest conservation practices at the landscape level. While space was freed for forest conservation, artificial pressure on land was created near the relocated villages and along the roads. Local communities are however now made liable for this land degradation (Lestrelin et al., 2011).

The leakage and additionality issues in our study area demonstrate the importance of making swidden systems and their dynamics visible for (a) correctly identifying their contribution to sustainable management of complex landscapes and (b) as a basis for negotiation of REDD+ benefit sharing. The question of “who is constrained by” and “who benefits from” REDD+ financing in a given area will certainly be crucial for the effectiveness and sustainability of the interventions.

5 Conclusions and outlook

In this article we presented an approach for putting swidden landscapes back onto the map. The case study in Viengkham swidden landscapes demonstrated that the approach allows analyzing land use trends and detecting degradation as well as reforestation. Particularly we can conclude for our study area, that (1) no pioneering swidden agriculture took place, neither between 2007 and 2009, nor between 1979 and 2009; (2) the swidden system is generally intensifying from long crop-fallow cycles to short crop-fallow cycles, (3) there is a potential problem of 'carbon leakage' as forest conservation within and near to the protected area most likely trigger degradation and deforestation outside the park boundaries.

We therefore recommend the use of the landscape mosaics approach as planning and monitoring method for REDD+ in other swidden landscapes. This approach allows locating processes of deforestation, forest degradation and reforestation and linking them to various types of land use change trends and drivers. Change matrices and corresponding maps highlight anomalies within the general land use change patterns. They inform on past land use extensification or intensification areas and would be crucial to detect leakage processes in a context of REDD+ intervention planned in or close to swidden landscapes. Using equal time steps, e.g. of five years, the landscape mosaics could be used for landscape change monitoring and carbon monitoring in a swidden compatible MRV-system (monitoring, reporting and verification) of a future REDD+ framework.

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