19 Finding Homogeneity in Heterogeneity: A New Approach to Quantifying Landscape Mosaics, Developed for the Lao PDR

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Abstract

Linking land cover information to human–environment interactions over large spatial areas is a key challenge for land change science in general, and research on swidden agriculture in particular. In the Lao People's Democratic Republic (Lao PDR), a country facing rapid and multi-level land change processes, this challenge hinders informed policy- and decision-making. Crucial information on land use types and people involved is still lacking. This article proposes an alternative approach to the description of landscape mosaics. Instead of analysing local land use combinations, we studied land cover mosaics at a meso-level spatial scale and interpreted them in terms of human–environment interactions. These landscape mosaics were then overlaid with population census data. Results showed that swidden agricultural landscapes, involving 17% of the population, dominate 29% of the country, while permanent agricultural landscapes involve 74% of the population and likewise cover 29% of the territory. Forests remain an important component of these landscape mosaics.

Keywords: Landscape mosaics; land use; land cover; meso level; Lao PDR; swidden agriculture.

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19.1 Introduction

One of the numerous challenges in the field of sustainability science relates to the call for a new mode of collaboration between scientists and decision-makers (Kates et al 2001; McMichael et al 2003). More concretely, any such new form of collaboration should comprise two key features. First, rather than being driven exclusively by academic interests and inquiry, research agendas should emerge from a close dialogue between decision-makers and researchers to identify knowledge needs and gaps. Second, research results should support informed and evidence-based decision-making. Hence, the levels and scales at which research results are aggregated and insights are produced must be defined taking account of the levels and scales at which most relevant decisions are being taken (Cash et al 2003).

Within land change science, which is an important component of sustainability research, the call for linking knowledge production with the needs of policy- and decision-making reinforces a fundamental challenge related to describing human–environment interactions beyond the local context. Land change science has drawn attention to the strong variation of human–environment interactions in time and space (e.g. Lambin et al 2003; Lambin and Geist 2004; Verburg et al 2008). Given that a growing number of factors at multiple spatial scales influence land use and land cover, and that these factors interact in chain-linked or nested ways (Hurni 1996), they produce dissimilar land cover and land use outcomes, thereby reinforcing the uniqueness of any local context (Ostrom 2007; Turner et al 2007). The resulting limited validity for out-scaling and generalisation has also been referred to as the "one place–one time syndrome" (Woodcock and Ozdogan 2004). Accordingly, a large body of land use literature consists of case studies dealing with human–environment interactions at the local scale. Only a limited number of studies and research initiatives have tackled the issue of linking land cover change to underlying processes at higher spatial scales; among these initiatives, the hotspot approach (Myers et al 2000; Achard et al 2002; Lepers et al 2005; Mittermeier et al 2005) and the meta-analysis approach (Rudel et al 2000; Geist and Lambin 2001, 2004) are particularly noteworthy. However, despite these interesting contributions, an operational solution for integrating land cover information with land use processes at a meso-level scale has not yet been found (Heinimann 2006; Verburg et al 2008).

In contrast with this knowledge gap, decision-making on land use at these levels is becoming increasingly relevant. Given that land resources in a glo-

balised world provide ecosystem goods and services for stakeholders at higher levels and more distant places (Foley et al 2005; GLP 2005), decisions and policies at the subnational to international levels are becoming increasingly important. At these levels, inventories of land cover are commonly available, whereas knowledge on social–environmental interactions is missing. The result is a growing disconnection between knowledge generation and decision-making.

These problems are very prominently illustrated in the Lao People's Democratic Republic (Lao PDR), a landlocked country in mainland Southeast Asia (see Figure 2 on p 384). This country, which is the geographical focus of this article, has a relatively small and unevenly distributed population, making its unused land resources a major development asset (Messerli et al 2008). With recent annual economic growth rates of around 8% and an economy based essentially on natural resources (World Bank 2008a), this asset is under considerable pressure (GoL 2000; Hirsch 2000, 2001; Rigg 2006). Crucial decisions will have to be taken in the near future on the unavoidable trade-offs between use and conservation of land and natural resources.

At a time when an increasing number of external actors are claiming access to land resources, more and more development interventions are being implemented across the country (Parnwell et al 1996; Woods 2003; Ducourtieux et al 2005; Fullbrook 2006). These influences lead to an ever-increasing fragmentation of spatial contexts in terms of development potentials and constraints (Badenoch 1999; Messerli and Heinimann 2007). The rural areas of the Lao PDR, which until recently could be spatially differentiated by few key factors, are currently facing a rapidly rising number of spatially relevant development drivers such as growing infrastructure networks, the extended reach of public policies, services and market opportunities, the availability of off-farm employment in commercial agriculture or mines, and others. As a result, spatial units with similar development potential and problems are becoming more and more fragmented and manifest ever smaller geometries. This, in turn, leads to a dilemma between the urgent need for knowledge to support evidence-based decision-making on the numerous land use interventions, on the one hand, and the growing difficulty of understanding the particularities of the differentiated and fragmented development spaces, on the other. The resulting growing uncertainty causes sustainable management of land resources to fade further out of sight. Meanwhile, the most basic questions remain unanswered: What is the current extent and availability of different basic land use types such as swidden, permanent, or commercial agri-

culture? What share of the Lao population is involved in each? What type of land use implies what trade-off between degradation and conservation of land resources?

The information needed to answer such questions can be gained through a considerable amount of case studies in different parts of the country. However, the validity and reach of case study results is often confined to very limited geographical areas. Aggregated information covering the entire country is scarce and of doubtful quality. Reasons for this include the often difficult and contested definitions of land use categories such as swidden cultivation (Mertz et al 2009b), the quality of data coming from agricultural reporting systems that have to correspond to government plans, and a high variety of land cover inventories with different data sets, methodologies, and classification systems. As a result, data on the extent of land use systems vary considerably (Padoch et al 2007; Schmidt-Vogt et al 2009) and the attribution of people involved in each of these systems is even more difficult (Messerli 2004; Mertz et al 2009a).

We hope to contribute to overcoming this knowledge gap by presenting an alternative approach that makes it possible to link land cover information with land use processes at a meso-level spatial scale, that is, at the district to national level. This can be achieved by describing and quantifying landscape mosaics, which shall comply with two distinct but complementary characteristics: (a) they refer to geographical areas that consist of spatial patterns of land cover and represent functional units in terms of human–environment interactions, and (b) they represent meaningful spatial geometries that can be related and overlaid with other spatial data layers, particularly socio-economic data derived from population censuses and household surveys.

19.2 An alternative approach to describing landscape mosaics

The concept of landscape mosaics owes much of its appeal to the promise that its spatial patterns reveal information about the underlying social and environmental processes and hence the human–environment interactions (Wu and Hobbs 2007). In other words, describing landscape mosaics should not only make it possible to integrate land cover inventories with land use processes over larger areas, but should also offer the potential to contribute to the generalisation of knowledge, in terms of gaining aggregated insights on human–

environment interactions at higher levels of spatial scale (Levin 1997).

An analysis of the limitations of current research initiatives described above reveals one underlying problem. It is epistemological in nature and becomes apparent when taking a social science perspective: we can only relate land cover changes to human action if we understand who the actors influencing the land are, and what the intention and meaning of their activities is. In other words, the researcher has the difficult task of having to interpret a social world which is already interpreted by the actors that inhabit it (Giddens 1991). Accordingly, such an interpretation can only be meaningful if it is performed in a contextual way, that is, within the relevant specific social, political, and economic spheres and related to a concrete space and time (Wiesmann 1998; Long 2001). Against this backdrop, the fundamental limitation of generalising land use processes through up- and out-scaling becomes clear. The interpretation is only valid in a specific context – often restricted to a very local setting – and becomes void as soon as we enter a new context.

As shown in Figure 1, the first step in frequently applied approaches to describing landscape mosaics often consists of interpreting human–environment interactions in a local context, allowing the translation of land cover into land use information (Step A1). The stumbling block often lies in Step A2. When analysing spatial patterns of land uses to describe landscape mosaics,

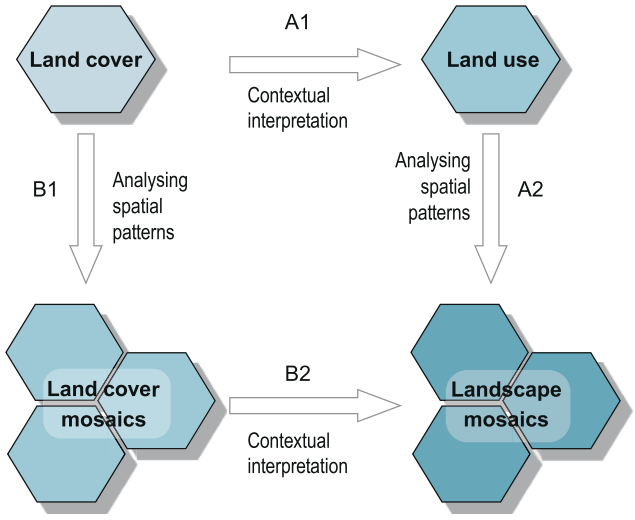

Fig. 1
From land cover information to landscape mosaics. While pathway A depicts the ordinary approach, pathway B shows the new approach proposed in the present article.

the contextual interpretations of few land cover patches are extrapolated to other places or to higher levels of aggregation. To these, however, the contextual interpretation is often no longer applicable; as a result, the process information contained in the landscape mosaic is flawed. While, for example, a secondary forest patch in a context of swidden cultivation may be used mainly as fallow land, a similar secondary forest in a different ethnic context may be of spiritual value or in a context of permanent agriculture might function as a source of timber and non-timber forest products.

In view of these difficulties, we propose an alternative approach to the description of landscape mosaics. This approach consists, first, of analysing patterns of spatial coexistence of different land cover types without trying to interpret their meaning in terms of land use (B1). This will result in land cover mosaics that are defined as specific combinations of land cover patches within a given geographical area. Only then are the resulting land cover mosaics interpreted within a sociopolitical context that corresponds, in terms of scale and spatial coverage, to the development issues at stake. In other words, we do not ask for the use of a single land cover patch and then try to extrapolate this information over larger areas; rather, we ask in what spatial compositions (i.e. land cover mosaics) land cover patches occur across the territory, and then interpret these compositions in terms of human–environment interactions. The resulting landscape mosaics no longer contain precise information on single land use patches but provide an interpretation of land cover mosaics as spatial manifestations of different land uses in the rural Lao PDR.

19.3 Methods

19.3.1 Study area and land cover data

In the Lao PDR, deficits in information and knowledge for decision- and policy-making with regard to land use are substantial from provincial to national levels. Therefore, this study attempts to provide information covering the entire territory of the Lao PDR. The Lao PDR is a landlocked, mountainous country, surrounded by Cambodia, China, Myanmar, Thailand, and Vietnam. It is a multi-ethnic and predominantly rural society in which most of the population depends on agriculture. In the mountainous regions swidden agriculture is widely practised, while in the alluvial plains of the Mekong and its tributaries irrigated paddy rice dominates the landscape. In 2002, forests still covered 41.5% of the country (GoL 2005), but they are disappearing at alarming rates of around 53,000 hectares per annum (World Bank 2008b). About

33% of the country's 5.6 million people live below the national poverty line (Epprecht et al 2008). With a per capita gross domestic product (GDP) of USD 485 in 2005, the Lao PDR is one of the poorest countries in the East Asia and Pacific region (UNDP 2007). In terms of human development it ranks 130th of 177 countries (ibid.). With this level of poverty, the country's natural resource base is of critical importance for poverty alleviation and growth.

Land cover maps were obtained from the Ministry of Agriculture and Forestry. The inventory captured the situation in 2002 and was based on visual interpretation of SPOT satellite images at scales of 1:50,000 and 1:100,000 for forest and land cover mapping and for field verification. The original land cover data comprised 22 categories, which we aggregated into 8 main land cover types: forest, open forest, bush and shrub, grassland, swidden fields, permanent agriculture, paddy rice, and other categories (rock, etc.). It should be noted that the category of swidden fields comprises only burnt plots, while any fallow swidden land appears under open forest, bush and shrub, or grassland. This makes a quantitative assessment of the actual extent of swidden agriculture impossible based on the original land cover data. Finally, we would like to point out that even though land cover data for different points in time exist in the Lao PDR, the differences in imagery, classification methods, and interpretation made it impossible to focus on dynamics of land cover change. This study is hence limited to an assessment of one point in time.

19.3.2 Describing land cover mosaics (Step B1)

Following the overall approach proposed in Figure 1, we first analysed spatial patterns of land cover to identify what we call land cover mosaics. For each pixel of 50x50 m of the land cover map we analysed the land cover categories of all neighbouring pixels within an area of 5x5 km. We thereby recorded the presence or absence of each land cover category within the window in a binary way (yes/no). Given the unequal share of land cover classes across the country (e.g. paddy vs. forests), an inverse weighting was applied to determine the threshold at which a patch was taken into account or not. This yielded information about the composition of land cover within this window, which was attributed to the central pixel. In this way, and using a moving window technique, we were able to attribute to every pixel a code denoting the land cover composition within its surrounding 5x5-km window. Adjacent pixels with the same code, that is, the same composition of neighbouring pixels, were then clustered into a land cover mosaic (Figure 2).

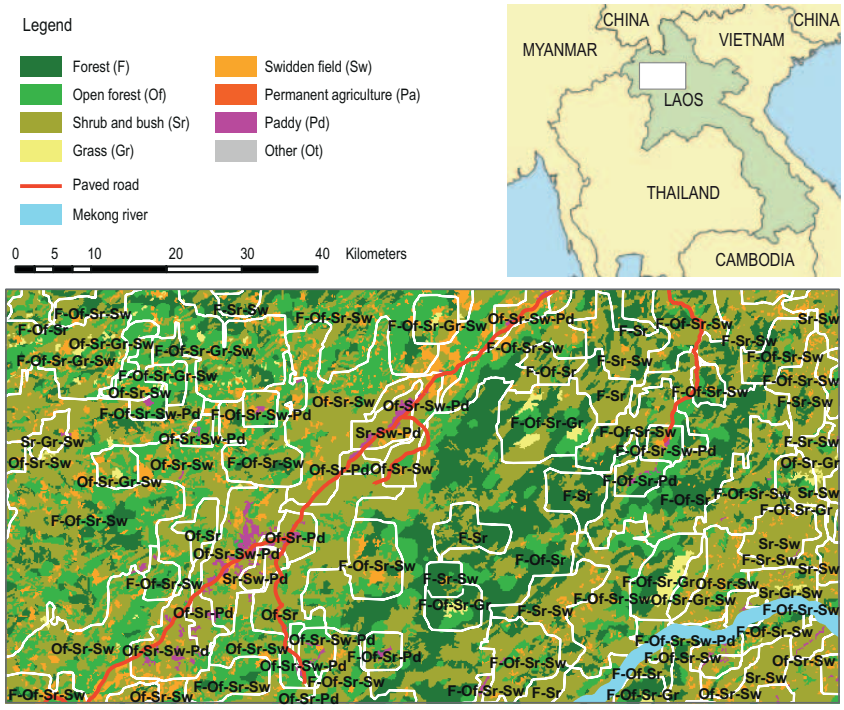

Fig. 2
Transformation of land cover patches into land cover mosaics (white borders). The codes correspond to the combination of land cover categories (see legend).

The window size is obviously a key factor determining the resulting land cover mosaics in terms of size, number, and combination of patches. The choice of 5 km was based on a study showing the impact of accessibility on land cover change in the Lao PDR (Heinimann 2006). Given the fact that the country's rural population lives in villages, Heinimann (2006) analysed the distance from the village at which the villagers' impact on land cover change fades out. This made it possible to approximate the average reach of rural actors and hence was useful in supporting the choice of a meaningful window size.

19.3.3 Contextual interpretation of landscape mosaics (Step B2)

The preceding step led to a description of land cover mosaics, which are defined as a specific combination of land cover patches within a given geographical area. We now proceeded to a contextual interpretation of these mosaics. In contrast to the preceding step, which can be performed on land cover data alone, this next step must take into account the social, economic, and political aspects of the development context in question, and is thus not transferable from one context to another. Moreover, it should be remembered

that in this step the focus of interest is no longer on the precise use of a single land cover patch but rather on the existence of certain land cover mosaics in the overall land use context at a meso level. Based on our previous knowledge and expertise regarding the development context in the Lao PDR, we focused on two key land use development issues that are of concern to national policy- and decision-makers: intensification of land use and degradation of forests and vegetative cover.

Intensification of land use: In its agricultural vision for the year 2020, the Government of the Lao PDR clearly foresees an increase in productivity based on sedentary and permanent systems (GoL 1999, 2006a). This is expected to support the improvement of food security at the national level and the alleviation of rural poverty, which is still related to swidden agricultural systems. Swidden systems are held responsible for the deforestation and degradation of natural resources as well as the low agricultural productivity per surface unit by parts of the Government of Laos (ibid.). By contrast, some scholars argue that there is sufficient land available to support the present population without any overall adverse effects on the environment or on the forest resource (Chamberlain and Phomsombath 2002; Raintree 2003). Moreover, it has also been suggested that rotational swidden systems remain sustainable and are the most productive means available for achieving food security and meeting livelihood needs (Fox 2000; Raintree 2003; Rigg 2005). For these scholars, the country's Malthusian squeeze is best interpreted as 'policy-induced', that is, as a result of current policies regarding land allocation, resettlement, and village merging. In summary, the reason for the incompatibility of such perspectives and the absence of a pragmatic dialogue partly lies in the lack of information and knowledge of which shares of the territory are currently under agricultural use at what intensity, and involving which part of the population in which places.

Degradation of forests and vegetative cover: Referring to the Lao PDR as the 'green jewel of the Mekong' (IUCN 2006), numerous stakeholders unanimously consider the tropical rainforest and the abundant natural vegetation of the country as a key development asset, even if the reasons for this are quite controversial. At the national level, forest and wood products represent an important source of revenue and still comprise a large share of total exports (Qiang and Broadhead 2002). Furthermore, the role of the forests in protecting watersheds for the growing number of hydropower dams is highly valued. At the international level, ecotourism and the potential future valuation of ecosystem services such as carbon sequestration or biodiversity con-

servation are becoming more and more important. At the local level, forests and especially secondary forests have also played – and continue to play – a central role in providing the livelihoods of rural families as they still represent an important source of food and provide a large array of other non-timber forest products (NTFPs) (ADB 2001; Rigg 2006; WFP 2007). The high pace of deforestation and forest degradation is thus an alarming phenomenon that curtails both short- and long-term development options.

It is not surprising that these two key issues related to land use policy and planning are closely intertwined and in many regards represent conflicting interests. Correspondingly, our contextual interpretation of landscape mosaics is based on the question of this trade-off. In other words: what does a given land cover mosaic, as derived from Step B1 above, represent in terms of agricultural intensification versus deforestation and degradation of the vegetative cover?

Figure 3 illustrates how the land cover mosaics derived from Step B1, which represent specific compositions of land covers, are attributed to one of the 16 types of landscape mosaics. Each landscape mosaic is characterised by the

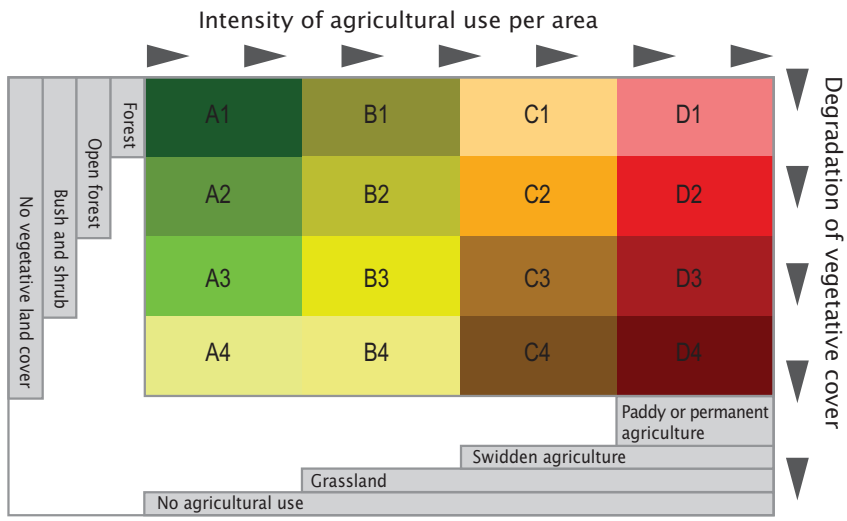

Fig. 3
Table chart illustrating the definition of landscape mosaics based on the trade-off between agricultural intensification and degradation of the vegetative cover.

Note that the presence of the most intensive agricultural land cover category in the composition of the land cover mosaic determines the choice of the column. Correspondingly, the least degraded form of vegetative land cover determines the row to which the mosaic will be attributed.

presence of its most intensive form of agricultural use and by its least degraded form of vegetative land cover. A swidden cultivation landscape mosaic, for example, is defined as a cluster of land cover mosaics that may be composed of any land cover except permanent agricultural fields or paddy (column C). A further differentiation is made using the specific conditions of forest and vegetation (using rows 1–4). The two corners A1 and D4 represent the most extreme poles of the trade-off between degradation and use of land resources, while D1 can be considered as a landscape mosaic where agricultural use has been intensified without a concomitant degradation of the vegetative cover. However, the limitations of the underlying land cover data should not be forgotten. On the one hand, it is a one-time data set and hence we cannot infer dynamics; on the other hand, the data do not allow for a complete differentiation between natural and plantation forests.

Following this classification, it will be possible to quantify different types of landscape mosaics, not only revealing the share of the territory under a certain type of land use, but also identifying all landscapes of which forests are still an important component. Moreover, this chart also functions as a map legend in Figure 4, which shows how this interpretation from land cover to landscape mosaics reveals interesting spatial patterns.

19.3.4 Overlaying landscape mosaics with other data layers

The definition of landscape mosaics as units representing trade-offs between agricultural use and degradation of forest resources also produced geometries that genuinely depict the different types of human–environment interactions. These geometries can be overlaid with other spatial data layers without it being necessary to revert to other a priori chosen geometries such as, for example, watersheds or administrative units.

A parallel research initiative in the Lao PDR had the aim of depicting socio-economic data at the highest possible resolution, that is, at the village level. Mainly based on the 2005 population and housing census (GoL 2006b), 70 indicators were calculated for each of the 10,547 villages and spatially illustrated in a *Socio-Economic Atlas of the Lao PDR* (Messerli et al 2008). This spatial disaggregation of socio-economic data which are normally available only in the form of province aggregates has added considerable value to the data of the population and housing census. Given the fact that in the Lao PDR no village boundaries are available for depicting the data, so-called village polygons were calculated based on equidistance in terms of travel

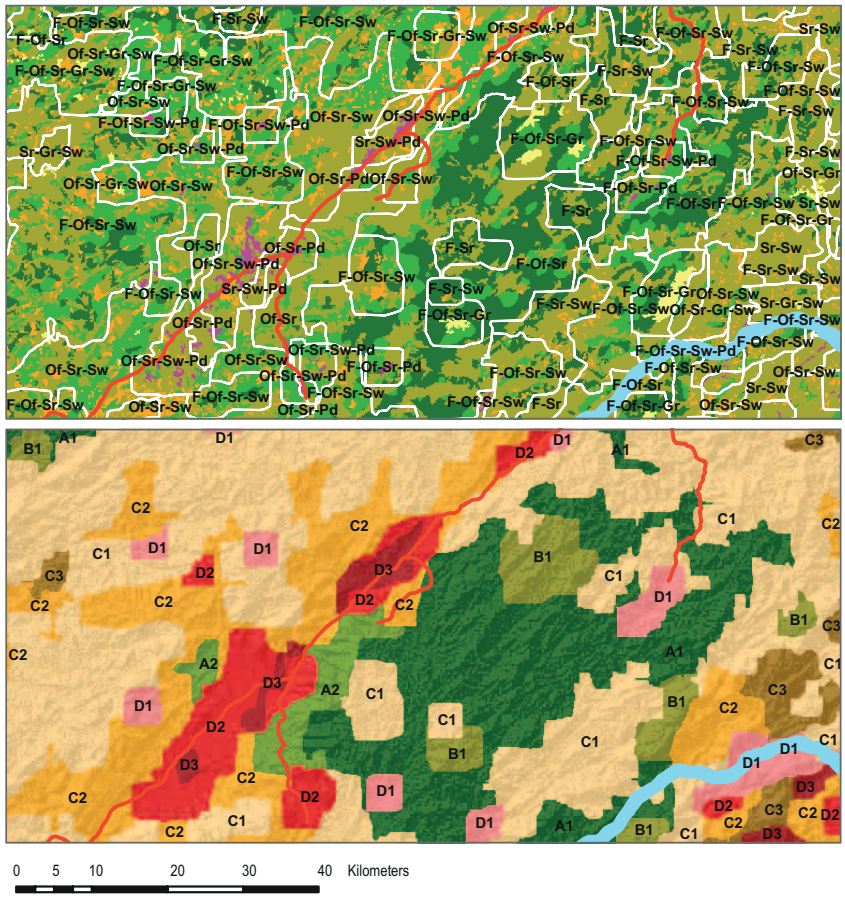

Fig. 4
Illustration of the interpretation of land cover mosaics (see above and Figure 2) as landscape mosaics (below). For the legend regarding the landscape mosaics please refer to Figure 3.

time from any two villages (Heinimann 2006; Epprecht et al 2008; Messerli et al 2008). These village polygons were then intersected with the landscape mosaics, making it possible to attribute demographic data from the population census to each landscape mosaic (Figure 5).

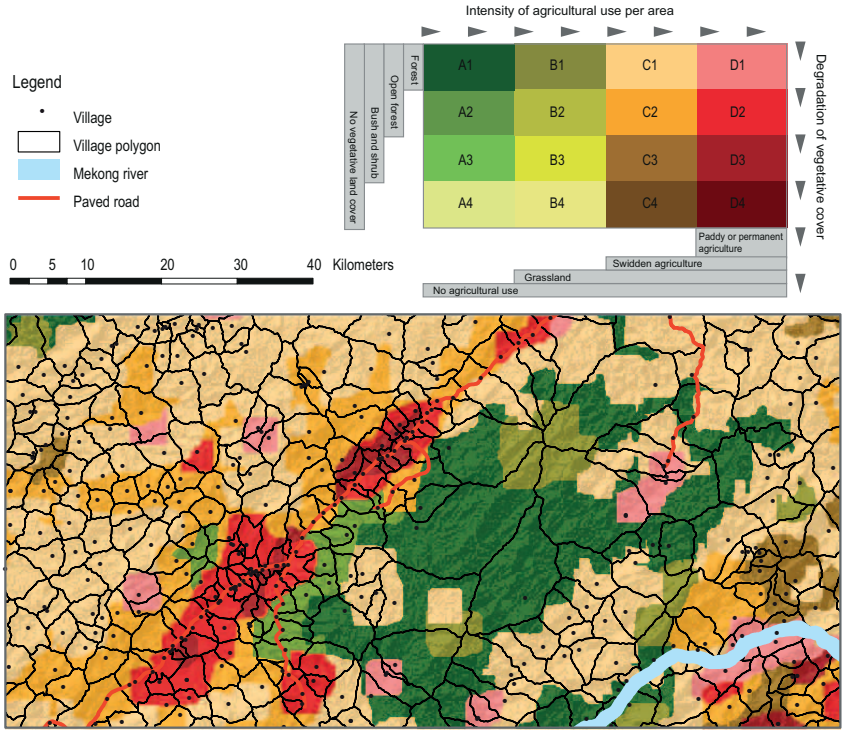

Fig. 5 Landscape mosaics overlaid with village polygons. The resulting intersects make it possible to attribute population census data to the different landscape mosaics.

19.4 Results

19.4.1 Describing land cover mosaics (Step B1)

Analysis of the approximately 92 million pixels containing land cover information on the territory of the Lao PDR using a moving window technique with a 5x5-km window resulted in the identification of 3,446 land cover mosaics. Each of these mosaics was composed of one to eight land cover classes and varied in size, with a median area of 34 km^2. On average, such a land cover mosaic was made up of three different land cover classes.

Even though the eight land cover classes could potentially be combined into 225 different compositions, only 120 actually occurred. A few of these compositions are clearly dominant and account for extensive shares of land (see Figure 6).

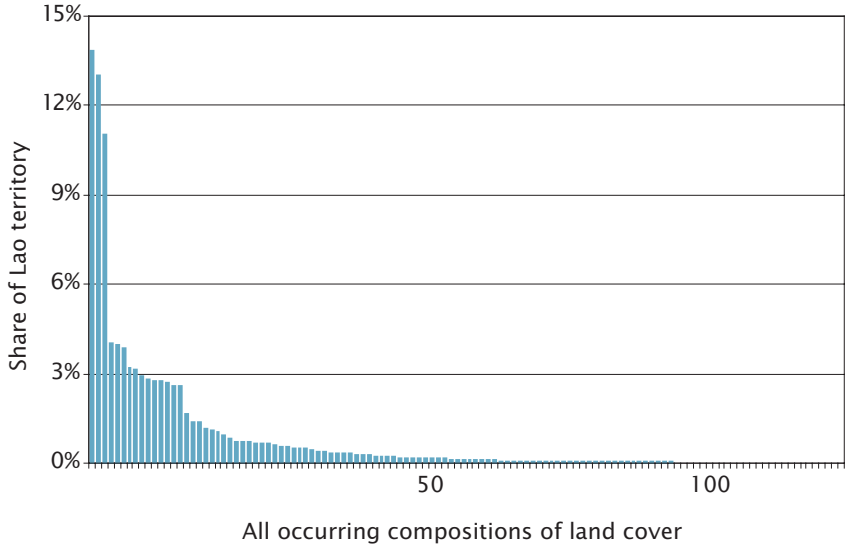

Fig. 6
Shares of land of the most important land cover mosaics in the Lao PDR. A small number of compositions make up a large share of the territory.

The six most widespread land cover mosaics together cover 50% of the territory of the Lao PDR (Table 1). It is striking that forest patches are part of all of these mosaics. This seems to substantiate the argument that despite the ongoing loss of coherent forest surfaces in Laos, forest patches still play a central role in supporting the livelihoods of rural families as sources of food and other timber and non-timber forest products (ADB 2001; Rigg 2006; WFP 2007).

19.4.2 Contextual interpretation of landscape mosaics (Step B2)

Against the backdrop of the most salient and controversial issue related to land use policy and decision-making at the national level – the intensification of agriculture versus deforestation and degradation of the vegetative cover – we interpreted the 120 different land cover mosaics as 16 different types of landscape mosaics. This resulted in a map of landscape mosaics of the Lao PDR and provided, for the first time, a quantification of the different shares of these landscapes throughout the country.

At a small scale, the map shows the general distribution of landscape mosaics across the country (Figure 7). Forested landscapes without significant agricultural use cover the central and eastern parts of the country, as well as the southern and northern tips. Landscapes composed of swidden agri-

Table 1

Composition of land cover mosaics	Share of land	Cumulative share of land
Forest – Open forest – Shrub	13.7 %	13.7 %
Forest – Open forest – Shrub – Swidden fields	12.9 %	26.6 %
Forest – Shrub	10.9 %	37.5 %
Open forest – Paddy	4.2 %	41.7 %
Forest – Shrub – Swidden fields	4.0 %	45.6 %
Forest – Open forest – Shrub – Grassland	3.9 %	49.6 %

Most dominant land cover mosaics in the Lao PDR and their respective shares of the territory.

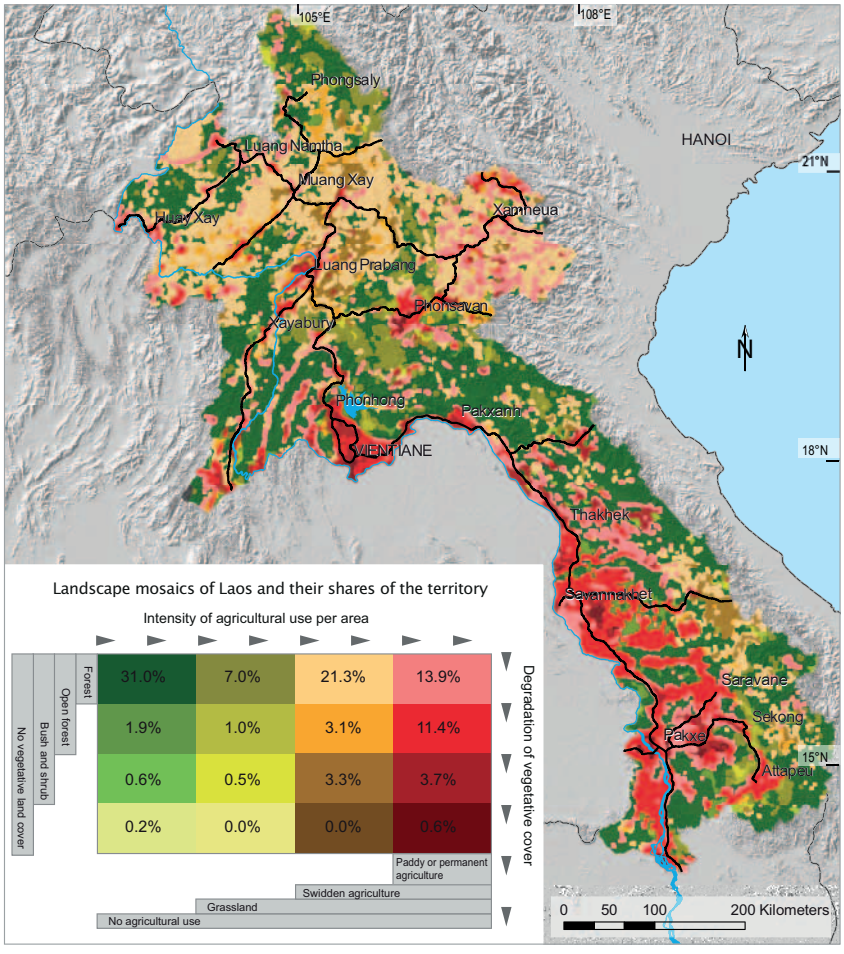

Fig. 7
Landscape mosaics of the Lao PDR and their respective shares of the territory. Each mosaic represents a trade-off between the status of the vegetative cover and the intensification of agricultural land use.

culture and different vegetative covers dominate the northern uplands, as well as parts of the Annamite Mountains on the eastern border with Vietnam. Permanent agriculture can be found in landscapes along the Mekong but is generally more widespread in the south, with the exception of the northeastern region around the provincial capital of Xamneua. At a larger scale, the map reveals that the landscape mosaics mimic the spatial gradients of land cover composition from peripheral to more central areas that extend around the urban centres and along the main roads.

In quantitative terms the chart reveals that in 2002 no agricultural use was detected on 33% of the Lao territory. Swidden agricultural landscapes, which show no sign of transition to permanent agriculture and manifest different conditions of the vegetative cover, accounted for a total of 28.2%, or approximately 6,500,000 ha. Finally, permanent agriculture and paddy farming were already dominating landscapes in 29% of the country. It is remarkable that in 2002 forests still played a very important role in all types of agricultural landscapes, being a component of 72% of all Lao landscapes. Furthermore, in 18.4% of all landscapes, there were at the very least patches of open forests. In other words, swidden and permanent agriculture was in most cases still practised in an environment coexisting with forests (this is true for 77% of total swidden agriculture and 47% of permanent agriculture, respectively).

19.4.3 Overlaying landscape mosaics with demographic census data

As mentioned above, this approach to landscape mosaics is intended to enable delineation of spatial units that are genuinely related to the types of human–environment interactions described above. This made it possible to overlay and intersect the map of landscape mosaics directly with the village data layers emerging from the 2005 population and housing census data (GoL 2006b) and depicted in the *Socio-Economic Atlas of the Lao PDR* (Messerli et al 2008). Figure 8 recapitulates the land shares of different landscape mosaics (left) and compares them with the shares of the population living in each landscape mosaic (right).

While landscape mosaics dominated by swidden and permanent agriculture occupy comparable shares of the Lao territory (28.2% and 29.0%, respectively), the population is distributed quite differently. A total of 16.9% of the population, corresponding to about 943,000 individuals or approximately

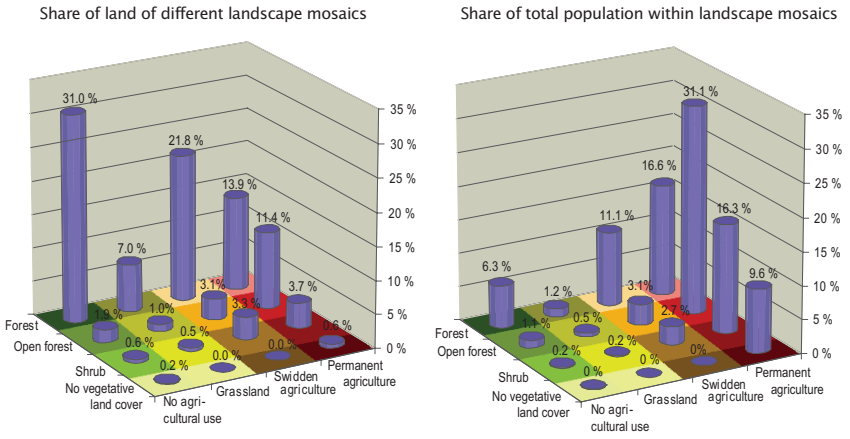

Fig. 8
Shares of total land and of total population within different types of landscape mosaics in the Lao PDR.

157,000 households, live in swidden landscape mosaics. A significantly larger portion of the population – 74% or 4.1 million people – are estimated to live within landscapes of permanent agriculture. It is therefore not surprising that these landscapes have quite a high population density, amounting to 152 persons/km^2 on average, while swidden landscapes are less densely populated at an average of 18.8 persons/km^2. It is noteworthy that population density is higher in landscapes where swidden agriculture is combined with open forest (24.2 persons/km^2) or shrub (19.9 persons/km^2) but lower where swidden agriculture is practised in dominantly forested landscapes (12.3 persons/km^2).

19.5 Discussion

In this article we have presented an alternative way of describing landscape mosaics. Instead of approaching landscapes as "land uses and their combinations in different patterns" (Tomich et al 2004, p 16) we have asked in what spatial compositions land cover patches occur across the territory (resulting in land cover mosaics), and then interpreted these compositions in terms of human–environment interactions. This approach and the results obtained are discussed below.

One of the key characteristics of this approach is that combinations and patterns of land cover patches are analysed before they are interpreted in terms of their use. In doing so, we have tried to find a solution for the difficulty of

extrapolating local contexts, to which interpretation is always bound. By delaying this interpretation and performing it at a higher level – in our case, in the context of subnational to national land use and development planning – we do, however, lose information at the local level – a level to which it is impossible to downscale our results in a meaningful way. In other words, having identified a landscape mosaic of swidden and shrub, we may accurately say that this region has lost its forest cover, and has not yet seen any transition to permanent agriculture. But we will not be able to define the precise use of the shrub in a certain place and time. Hence we have gained accuracy at the meso level at the expense of accuracy at the micro level. This insight underlines the importance of working with complementary approaches at different levels.

We believe that the proposed approach could be adapted to other situations in different regions. Yet, two important issues should be considered in this regard. First, even if the analysis of land cover mosaics (Step B1) using the moving window technique depends on neither a specific type of land cover data nor the human–environment context of the study region, the ideal size of the window of analysis cannot be derived empirically. It must be defined by the researchers. As mentioned earlier, the size of the window influences the composition and size of the resulting landscape mosaics. Therefore, it is important that the window size be chosen with care. We propose that the choice should be based on the expected spatial reach of the main actors inducing land cover change. Second, the contextual interpretation of land cover mosaics to define landscape mosaics (Step B2) is again highly dependent on the research questions and the development context of the study. The definition of the main features of the landscape mosaics can be adapted to the knowledge needs in the given context. We can imagine that agricultural intensification and deforestation could be replaced by other key issues of land change science such as urbanisation, commercialisation of land use, and others (Turner et al 2007), or that they could be adapted to support the analysis of ecosystem service provision and land functions (Verburg et al 2008). Furthermore, it should also be possible to work with tripolar charts to define landscape mosaics (Riiters et al 2009).

Finally we would like to stress the importance of the newly emerging geometries of the defined landscape mosaics. We believe that they are more accurate for capturing complex spatial manifestations of the multidimensional land use strategies of rural households (Wiesmann et al 2000) than are ordinary measures such as, for example, paddy land per community area or for-

ests per watershed. The persistent use of such spatial units in negotiations and planning of integrated development strategies reinforces the problem of the spatial mismatch between human and environmental systems, and eventually also between problems and adequate solutions.

This study was intended to contribute to filling some of the current knowledge gaps in policy- and decision-making in the Lao PDR. The description of the landscape mosaics provides a basis for making reasoned estimations about the spatial shares of different generalised land use types, the people living within these systems, and the trade-off in terms of loss of forest and vegetation cover. In the case of swidden agriculture, the combined information on landscape mosaics and people proves particularly important. While reasonable and recent estimations of swidden landscapes were lacking in the past (Schmidt-Vogt et al 2009), the assessment of the number of people engaged in swidden cultivation is even more difficult (Mertz et al 2009a). In the Lao PDR, our results will help to review and amend earlier estimations either focusing on the extent of swidden agriculture (Chazee 1994; Hansen 1998) or on the people involved (Fujisaka 1991; GoL 2002). Furthermore, the new insights gained through this study will be particularly important in reflecting on the mainstream of current development thinking by governmental agencies as well as international development partners. Among many of these agencies it is still widely believed that the most promising solution for lifting people out of rural poverty lies in moving away from allegedly environmentally destructive swidden agriculture to sedentary and permanent agricultural systems. Even if, in the long term, this belief may be justifiable, it threatens to cloud the view of more immediate problems. The results show not only that in 2002 swidden agriculture was still being practised in landscapes with a relatively intact vegetative cover and considerably low population densities, but also that some landscapes of permanent agriculture were already manifesting high population densities. It seems, therefore, that public policies which artificially increase pressure on permanent agricultural land by means of, for example, new land tenure schemes, village relocation and/or merging programmes, or ceding fallow land to investors for agricultural concessions (Chamberlain and Phomsombath 2002; Raintree 2003; Ducourtieux et al 2005; Rigg 2005, 2006) should be carefully re-considered. Finally, we were also able to draw attention to the 7.5% of the population still living in mostly forested regions with no obvious agricultural use. These people and their livelihoods should not be ignored when making decisions and policies on environmental issues and land development.

In summary, the depiction of landscape mosaics raises the issue of past and future pathways for land use in the Lao PDR. Spatial patterns strongly suggest that unpopulated and forested areas are transformed into swidden landscapes, which then gradually lose their vegetation cover. Depending on a series of agro-ecological, but also socio-economic factors, this is followed by a distinct rather than a gradual transformation into permanent systems. Against this backdrop, current interventions by multiple development stakeholders, many of which pursue the goals of food security, poverty alleviation, and sustainable natural resource management, could be reviewed. Despite the preference for simple solutions for complex problems, different strategies for different types of landscape mosaics should be developed to pursue these goals. As landscape mosaics vary across the territory, spatially differentiated strategies must be applied across the country. In other words, there are no universal solutions or panaceas for sustainable transitions of human–environment systems (Ostrom 2007). Conversely, the map of landscape mosaics could serve as a tool to assist development partners in targeting intervention sites and support the out-scaling of innovative solutions from one context to another. We can imagine that, for example, the successful establishment of a livestock breeding and marketing programme in a degraded swidden cultivation landscape could be difficult to transfer to a nearby village where permanent cash-cropping represents the main source of revenues. Using the landscape mosaics data, other – even distant – regions with similar limitations in terms of population density and scarce land resources could be identified as a more promising context for out-scaling.

19.6 Conclusions and outlook

In this article we have presented an alternative approach to relating land cover information to human–environment interactions over large areas – an issue which remains a key challenge for land change science in general and for research on swidden agriculture in particular. We propose to transfer the interpretation of land cover in terms of its use from the local to a meso-level spatial scale in order to avoid the need for frequently impossible extrapolation of the specificities of local contexts. Based on an initial dialogue with development partners we believe that this information helps to fill the growing gap in urgently needed knowledge for informed decision-making at this level. As development in the Lao PDR follows an ever-accelerating economic pace, and as the number of interventions impacting on the use of land rapidly grows, spatial patterns become more complex, and no one district or

village seems comparable to another. In this context, the description of landscape mosaics helps to balance the need for a highly contextual perspective with the need for generalisation at higher levels. We think that such a balanced picture is particularly necessary for designing policies and to inform decisions in the field of swidden systems, where spatial and thematic differentiation is a precondition for avoiding the trap of ideological, political, or technical bias and oversimplification.

We do not think of this knowledge at the meso level as an alternative to micro- or macro-level studies, but, rather, as a complement necessary to bridge and initiate a dialogue across different scales. Accordingly, we identify a threefold need for future research. First, the 16 landscape mosaics should be related to local-level case studies to obtain a better understanding of the underlying land change processes and enhance knowledge about related trajectories of land use. Transitions between swidden and permanent agriculture seem to be of particular importance in this respect. Second, research at the meso level should be continued as well. Landscape mosaics can be related to other available socio-economic data layers such as poverty and ethnicity. A more realistic picture of the poverty situation in different swidden landscape mosaics is expected to be particularly revealing. Finally, a spatially explicit analysis of the actors influencing and governing different landscape mosaics will be crucial for further support of policy- and decision-making.

Endnotes

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