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Environmental Cognitions, Land Change and Social-Ecological Feedbacks: Local Case Studies of Forest Transition in Vietnam

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Abstract Forest transition — i.e., the shift from decreasing to expanding forest cover — in the northern mountains of Vietnam was analyzed at the local scale in four villages from the 1970s to 2007–2008 to understand feedbacks from local environmental degradation on land uses, the conditions under which such feedbacks occur, and their possible roles in the transition. Remote sensing data were combined with field surveys including interviews, group discussions, mental and participatory mapping, observations and secondary sources. The feedbacks from environmental degradation and changes in the provision of ecosystem services to land practices via environmental cognitions were analyzed. The case studies showed that forest scarcity was perceived, interpreted and evaluated before possibly affecting land use practices.

Keywords Deforestation · Reforestation · Ecosystem services · Vietnam · Land use change · Shifting cultivation

Introduction

Explaining land use/cover change requires understanding the dynamic coupling between human societies and their ecosystems embedded in social-ecological systems (SES) (Lambin *et al.* 2003; Ostrom 2009). Human-induced environmental change can affect the production of ecosystem services and goods, and in turn these changes can impact human behaviors. Land use systems undergo structural transformations through the interplay between local social-ecological feedbacks and exogenous socioeconomic and policy changes (Lambin and Meyfroidt 2010). Tropical deforestation has long been viewed as a continuous linear process, but nonlinear dynamics in forest cover changes are increasingly studied. Vietnam has recently experienced a forest transition — shift from shrinking to expanding forests (Meyfroidt and Lambin 2008a, b). Human responses to the decline of forests caused by human activities can drive forest transitions (Meyfroidt and Lambin 2011), but this depends on perceptions of forest degradation and scarcity. Scarcity is neither exclusively a social construct nor a physical reality, but the product of human cognitive processes triggered by environmental change. Understanding forest and land use transitions therefore requires analyzing human cognition, i.e., mental processes. This paper describes an empirical study of land changes, environmental cognitions, perceptions of forest degradation and feedbacks in four villages of the northern mountains of Vietnam, to show how environmental and land changes were perceived, understood and evaluated by local agents and affected their behavior and land use practices, and thus subsequent environmental and forest cover changes.

In land change science and human ecology, local perceptions of environmental change have rarely been directly linked with actual practices and behaviors. Yet local actors often perceive environmental services differently than land planning authorities and react in unanticipated ways to new policies. Current models of decision-making and behavior in land change science, usually based on variants of rational choice theory or of heuristics, often assume mechanistic responses to environmental signals and a stable set of preferences, beliefs and decision-rules (Meyfroidt 2011; Villamor *et al.* 2011). Although useful in stable or linearly changing contexts, these perspectives are insufficient to understand how agents may modify their beliefs, attitudes, preferences or utility function, and/or heuristics to respond to qualitatively changing environments. Many studies explore how local agents adapt to environmental change that

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they cannot mitigate — typically climate change — (e.g., Mertz *et al.* 2009), but few focus on how local land managers rely on their own environmental perceptions, knowledge, evaluation and decision-making tools to directly act on the causes of environmental change (Lauer and Aswani 2010).

Feedbacks from environmental change on cognitions can be "direct" when they modify only the perceived state of the environment and parameters of the decision-making, or "indirect" or "transformative" when they modify beliefs, values, and/or decision-making strategies and possibly subsequently social norms (Fig. 1; Meyfroidt 2011; Reed *et al.* 2010). Social-ecological feedbacks are mediated by the cognitive processes of perception, interpretation and evaluation of environmental change (Meyfroidt 2011). The rate and saliency of change (Clitheroe *et al.* 1998, Dayton *et al.* 1998, Rogan *et al.* 2005), traditional ecological knowledge (Berkes 2008) and different forms of practical engagement with the environment (Ingold 2000) influences whether environmental change is perceived early enough to allow for effective reactions. Causal attribution of the change — in particular attribution to natural variability versus anthropogenic causes — depends on the beliefs, worldviews and values of the agents, and influences the perceived severity of the change, responses seen as appropriate and expected consequences (Brown *et al.* 2005; Meyfroidt 2011; Schad *et al.* 2011). Cognitions about the environment can also be acquired through social learning — i.e., a change in understanding that is situated within wider social units or communities of practice and operates through social interactions (Reed *et al.* 2010). Evaluation of the importance and valence of the resource and its change, influenced by beliefs, values and emotions, will affect the commitment to mitigate or reverse these changes. Pro-environmental attitudes based on utilitarian beliefs and values are associated with distant and indirect behaviors such as policy support (Rauwald and Moore 2002), while emotional cognitions such as a sense of connectedness to nature are associated with local and practical actions (Hinds and Sparks 2008; Kaltenborn 1998; Stedman 2002). The perceived possibility to predict, control and improve the future state of resources affects decisions and commitment (Armitage and Conner 2001; Bandura 1997). Without a belief in their ability to control environmental events, local agents will tend to assess changes as being irreversibly engaged. This study explores four hypotheses about the role of local-scale cognitions on responses to environmental degradation: (i) early perception of environmental change is necessary to allow for effective reaction; (ii) the causal attribution for environmental degradation will influence the type of reactions selected; (iii) more highly valued resources will elicit more committed responses to degradation; and (iv) a lower perception of self or group efficacy will limit reactions to mitigate environmental change.

A national-scale statistical analysis of forest transition in Vietnam (Meyfroidt and Lambin 2008b) showed that districts with low forest cover at the turning point had higher

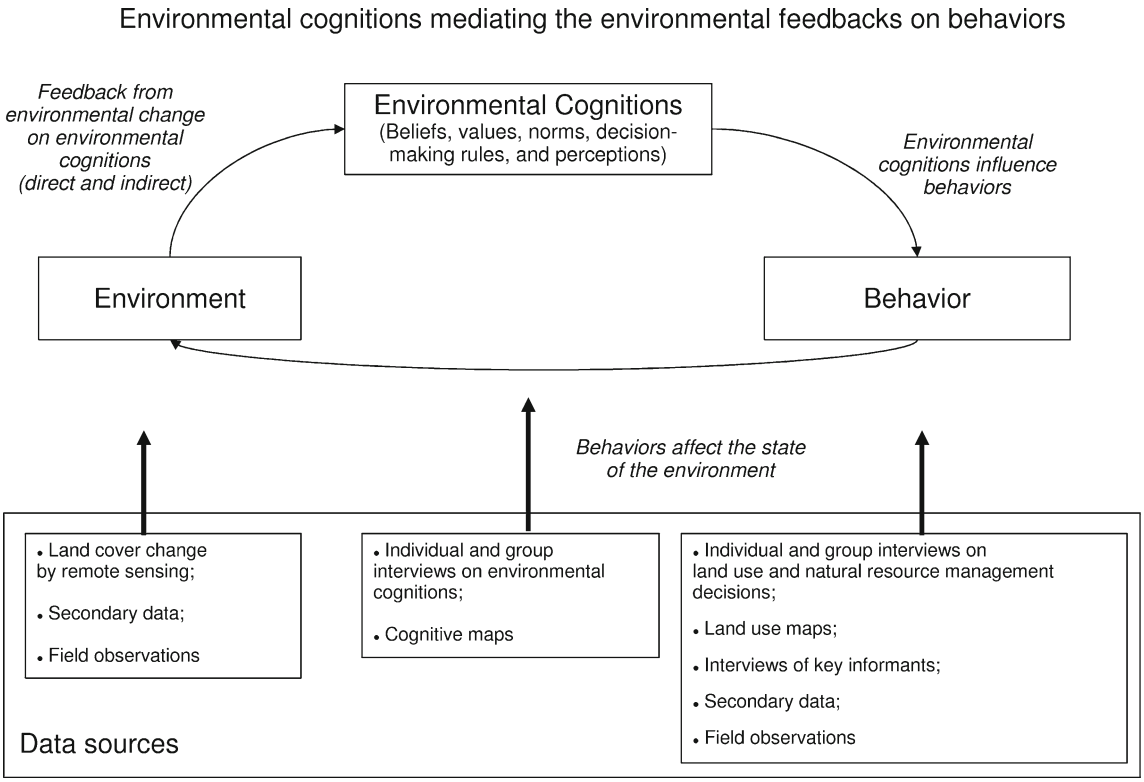

Fig. 1 Conceptual model of environmental feedbacks via cognitions

rates of reforestation, suggesting that local forest scarcity could motivate investments by local landowners in forest conservation, tree planting and more intensive forest management by driving up timber prices (Hyde *et al.* 1996), and/or by increasing awareness of adverse effects of deforestation such as floods and land degradation. To date, the latter has only been shown to influence national level policies (Durst *et al.* 2001; Lambin and Meyfroidt 2010; Mather *et al.* 1999; Mather and Fairbairn 2000; Wenhua 2004). Possible mitigation responses by local actors remain unclear. Profound socioeconomic and political changes affected the uplands of Vietnam during the last decades (Meyfroidt and Lambin 2008b). Cooperative agriculture of paddy lands, established during the 1950s–1960s, was progressively dismantled during the 1980s with the privatization of agricultural production and the liberalization of markets. Introduced in 1991, land zoning defined three types of forestry land — defined as land covered by forest or planned for forestry uses —: forests for protection of watersheds and from land degradation; production forests; and special-use forests of high biological or cultural value. Through the 1993 Land Law, forestry lands were allocated to households along with rights and duties depending on the category of forest and actual vegetation (MARD 2003). The government also initiated reforestation projects by providing seedlings and labor fees to participating households. In the study areas these policies constitute the main exogenous changes that interacted with local perceptions of environmental change to cause locally specific changes in forest cover.

In the four village case studies we quantitatively measured and linked the three components of the feedback loop: (i) environmental changes, (ii) cognitive features that are part of the perception, interpretation, evaluation and decision-making steps, and (iii) the actual behaviors and land use practices (Fig. 1; Meyfroidt 2011). The two objectives were to explore the four hypotheses proposed above and the further hypothesis that forest scarcity may contribute to a forest transition by influencing local land uses. We discuss the conditions under which this takes place, and, although not the primary focus of the paper, the main outcomes of the forest transition for local livelihoods in the four study villages.

Materials and Methods

Overview

Different methods were combined to analyze the three components of the feedback loop (Fig. 1). Forest-cover changes were measured by remote sensing, validated by fieldwork. Environmental cognitions of the local land managers were assessed through several types of interviews and participatory approaches and mappings. Land use practices were reconstructed using participatory mapping, remote sensing, interviews, and land use statistics. Additional data including land tenure and land zoning maps and histories of land use policies were collected. Then, process-tracing analysis was used to describe the detailed steps of the causal chains of the feedback loop from environmental cognitions to outcomes in three variables — transition in forest area, in forest density, and in the satisfaction about forests by villagers (George and Bennett 2004). Analysing the spatio-temporal patterns of the land use/cover changes and land zoning allowed validating the reforestation processes described by local informants. Alternative hypotheses were discussed. Cognitions and decisions vary among agents, but the objective was to reconstruct the main social-ecological dynamics in each village as a unit of analysis. Disagreements or divergences possibly affecting these conclusions were assessed. Sensitive issues, including land use policies, timber harvesting, and possible illegal activities, were addressed by cross-checking and confronting data from different sources. For full methodological details and additional results, see Meyfroidt (2009).

Selection of Study Sites

The four villages were selected to allow for within-case study and controlled comparison (George and Bennett 2004). To study the role of environmental cognitions in land use transitions, the communes were chosen to control the main exogenous forces affecting both forest cover and environmental cognitions of local actors. Dynamics of deagrarianization (Rigg 2006) and outmigration (Phan and Coxhead 2010) occurred over the recent decades in many agricultural regions of Southeast Asia, and in some contexts similar dynamics have been shown to lead to land abandonment and reforestation (Meyfroidt and Lambin 2011). Thus, we focused on places that were poor, remote and with an agriculture-based economy, excluding the areas with large deagrarianization dynamics and/or agricultural intensification previously shown to allow for smooth setting aside of forestry land (Sikor 2001, Castella and Quang 2002), as well as areas with large-scale reforestation programs. The objective was not to find places that were entirely preserved from exogenous influences, but controlling these allowed easier assessment and separation of the respective influences of local social-ecological feedbacks.

In each of two communes selected in two different regions of Vietnam we chose two villages,[1] one in a valley, populated by an ethnic group traditionally combining paddy rice with shifting cultivation (Tran 2003), and the other in uplands and populated by an ethnic group traditionally

[1] The four villages were Khang and Na Da in Xuan Lac commune, and Hoc and Pa Dong in Ta Hoc commune.

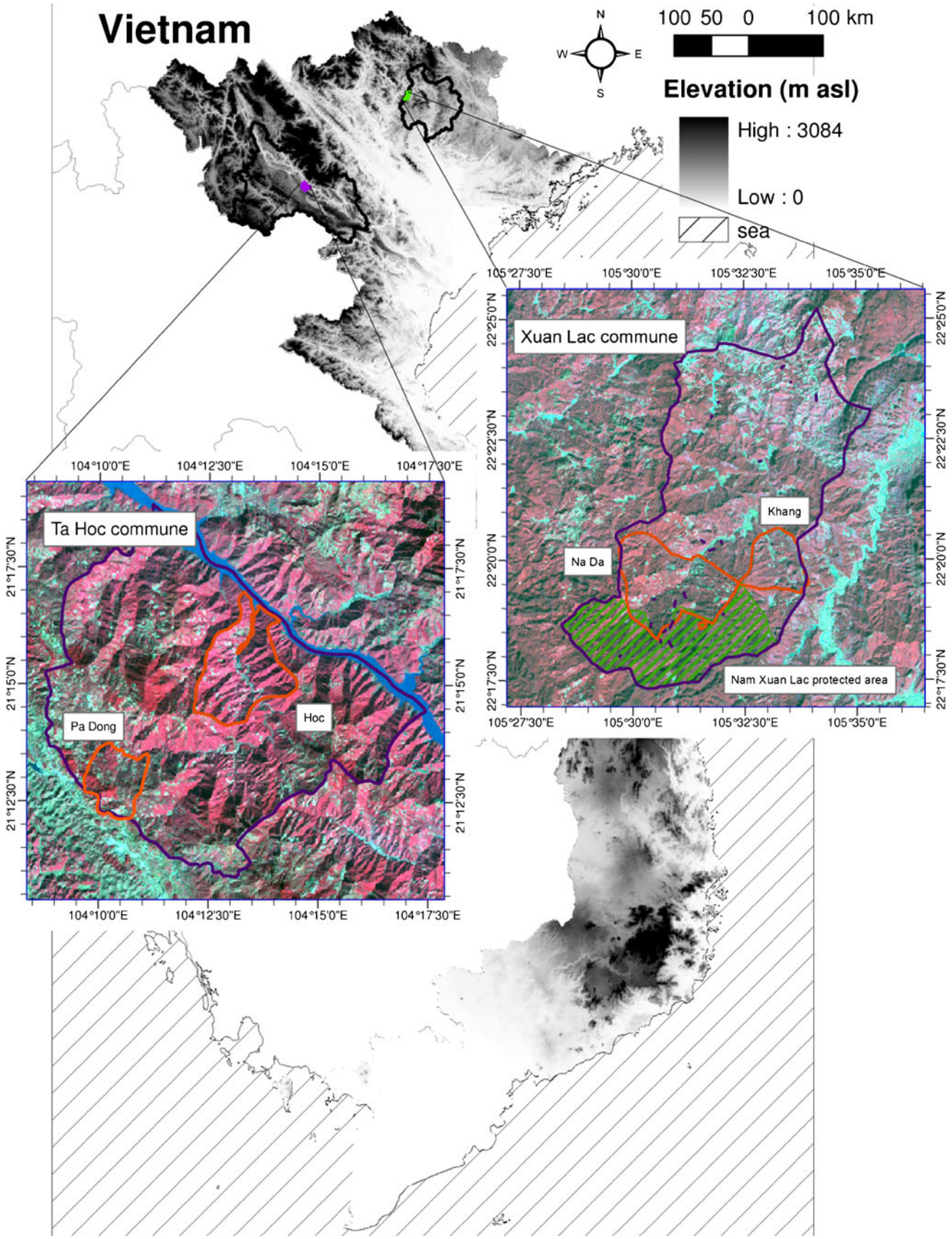

Fig. 2 Location of study sites, overlayed on Landsat infrared color composites

Table 1 Socio-political history of the study communes

Events	Xuan Lac (Khang and Na Da villages)	Ta Hoc (Hoc and Pa Dong villages)
Decollectivisation and land allocation	End of cooperatives and Tay families reclaiming the paddy land in 1990–1991. Allocation of forestry land: some area allocated with Green Books (temporary certificates) in 1993; most area allocated with Red Books (stable certificates) in 1995, finalisation in 1998.	End of cooperatives in 1985–1986. Allocation of agricultural land in Hoc in 1995. Allocation of agricultural and forestry land in the whole commune in 1998.
Land use zoning	Zoning of protection and production forests initiated in 1998 and formalised in 2001. Revised in 2005. Classification of the special-use forest in 2004 (Nam Xuan Lac preservation area).	Zoning of protection forest in 1991 (project 219) in Hoc and in 1995 (project 747) in Pa Dong.
Reforestation programs	Vietnam-Finland Forestry Sector Cooperation Program (2001–2003) in Na Da. PAC program (2004–2006) in Na Da. CARE program (2006–…) intially in Na Da and then Khang. Commune reforestation program (2005–…).	Project 219 (1991–1992) in Hoc. Project 747 (1995–2005) in the whole commune. Decision 06 (1994–1997) in Pa Dong. Forestry University (2004–…) project in Pa Dong.

Sources: fieldwork and official documents

relying mostly on shifting cultivation. This allowed understanding the respective roles of the administrative, biophysical and economic environments. Finally, the selected communes were thought to have experienced a forest transition, so that effects of forest decline on environmental perceptions and responses of local agents could both be analyzed. The study sites were therefore not representative of the average Vietnamese upland commune and we do not claim that it is possible to extrapolate our observations for the whole of Vietnam. As described above, strong political and socioeconomic forces were important causes of the forest transition (Meyfroidt and Lambin 2008b), but in this analysis they are treated only as control variables. Considering these criteria, the study sites were selected by preliminary surveys, with collaboration from the provincial and district administrations. Xuan Lac is an isolated commune in the north of Cho Don district in Bac Kan province in northeastern Vietnam (Fig. 2; Tables 1 and 2). Khang is a Tay village in a small valley bottom occupied by paddyland (Fig. 3a). Tay farmers traditionally practice a composite agricultural system with paddy rice as the cornerstone, complemented by shifting cultivation of upland rice and maize with short fallows (Castella and Erout 2002). Na Da is a Dao village upstream of the main valley of Xuan Lac commune (Fig. 3b), where farmers traditionally practice upland rice cultivation in short cycles of 2–3 years followed by long fallows, typically 20 years (Mellac 2000). Ta Hoc is located in Mai Son district in Son La province, in the mountains bordering the Da River. The commune was affected by several land zoning and reforestation projects specifically aimed at protecting the watershed of the Hoa Binh dam, the most important hydroelectric facility in Vietnam, located downstream on the Da river. Situated along a deep valley at the confluence with the Da river (Fig. 3c), Hoc is occupied by Black Thai farmers who traditionally combine paddy rice farming in the valley bottoms with rotational swiddening on the hillsides (Sikor and Dao 2002). Yet, Hoc, due to its location, has almost no paddylands. Pa Dong is a Hmong village located in the southern highlands of the commune, with gentler slopes and closer to the district town than Hoc (Fig. 3d). Settlements are located in a small depression, surrounded by two forested hills. Over the last centuries, Hmong have been primarily living in the uplands and relying on clearance of mainly old-growth forest, followed by several years of cultivation, typically around five, and then migration to new areas when the soil is exhausted and the land becomes too weedy (Corlin 2004).

Remote Sensing Measuring of Land Use/Land Cover Change

Time series of Landsat remote sensing images from the dry seasons in 1973–1993–1999–2007 (for Ta Hoc) and 1975–1993–2000–2007 (for Xuan Lac) were co-registered, radiometrically normalized, and geo-referenced. The images were then processed to analyse land cover and land use changes. Firstly, supervised classifications were used to separate each image in four classes: (i) water; (ii) clouds; (iii) built-up land, bare soils and sparsely vegetated lands – including clear-cuts, croplands, grasslands and 1 or 2 year-old fallows, hereafter "bare land," and (iv) all other vegetated lands, including older fallows, shrublands with different tree densities, perennial crops, tree plantations and forests of different types and densities, hereafter "natural vegetation." This simple classification system was designed to maximize the accuracy of land cover maps and facilitate the analysis of land cover trajectories. Secondly, post-classification comparisons across the four dates were used to analyze trajectories of vegetation successional patterns and forest regrowth: "uncleared forest" corresponded to all natural vegetation pixels stable across the four dates; "shrubs" to the natural vegetation pixels at each time that were classified as bare land at the previous date; and "secondary/planted forest" to pixels classified as natural vegetation since at least the previous period, but which had been

Table 2 Main features of the study villages

	Khang	Na Da	Hoc	Pa Dong
Biophysical features				
Climate				
Average annual rainfall	1850 mm		bw 1500-2000 mm	
Average annual temperature	22°C		20°-22°C	
Dry season	October to March		November to April	
Average temperature	Around 17°C		na	
Rainfall	70 mm monthly		150-200 mm	
Rainy season	April to September		May to October	
Average temperature	Around 25°C		na	
Rainfall	July to September: 300 mm monthly		Peaks in July to August	
Altitude of settlements (m)	300	350	200	800
Lithology	Schists and limestone outcroppings		Limestone and schists	
Main soils types	Poor Acrisols		Fertile Ferralsols	
Human features				
Distance to the district town	30 km	40 km	30 km	14 km
Accessibility to the district town	Car road	Earth road for 3 km, then car road	Car road	Earth road for 2 km, then car road
Ethnic group	Tay	Dao	Thai	Hmong
Traditional land use system	Composite system with paddy rice and shifting cultivation with short fallows	Shifting cultivation with long fallows	Composite system with paddy rice and shifting cultivation	Pioneer shifting cultivation
Population in 1975-1980 (people)	70	46	130	165
Population in 2007 (people)	121	234	515	675
Total village area in 2007 (ha)	426	1091	1123	504

Sources: fieldwork and Le 1998; Bal *et al.* 1997; Mellac 2000; Wezel *et al.* 2002; Sterling *et al.* 2006. *na* not available

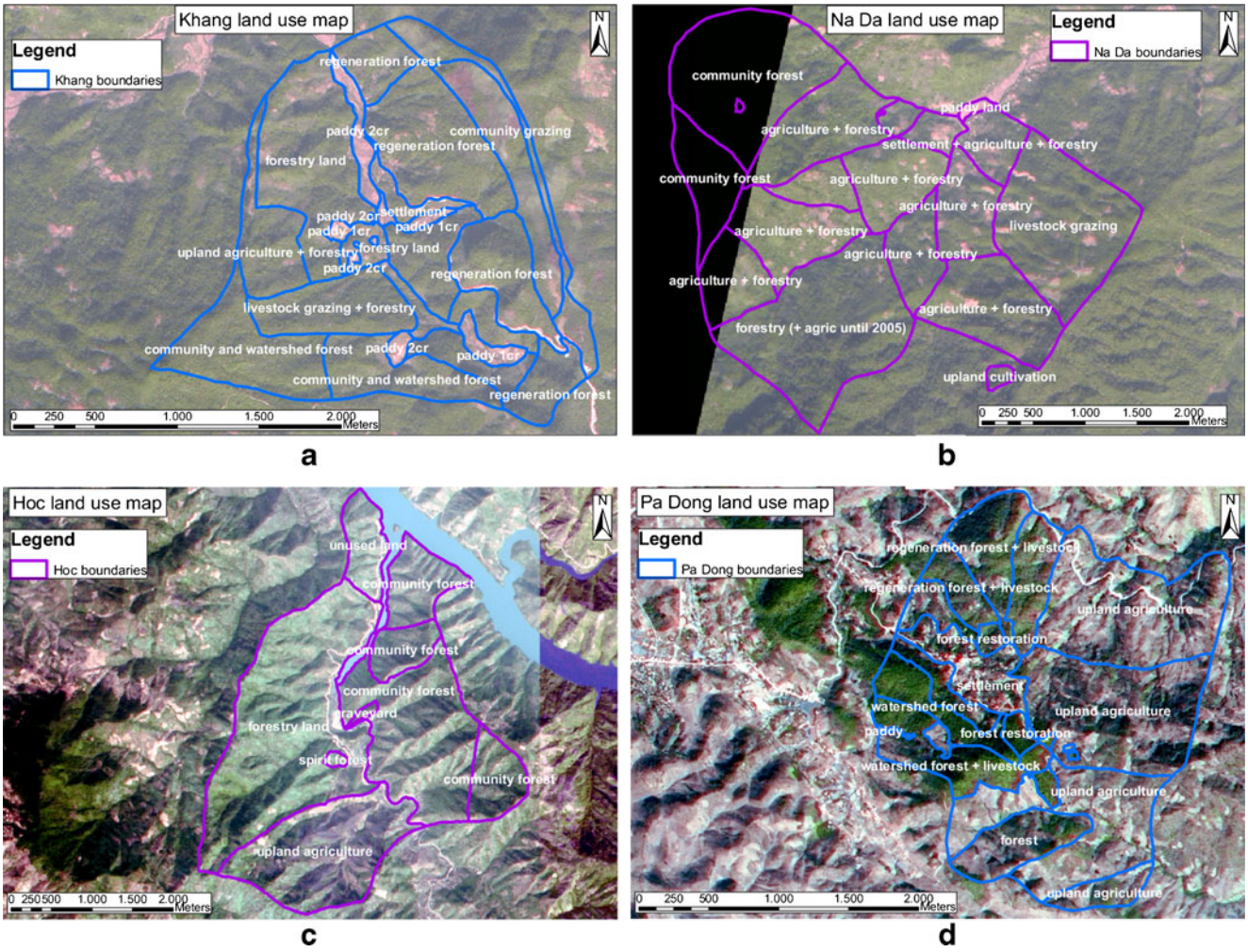

Fig. 3 Participatory land use maps in Xuan Lac and Ta Hoc. **a** Khang. **b** Na Da. **c** Hoc. **d** Pa Dong. *Background*: SPOT 5 image of 2005

cleared in the past. The accuracies of the classifications for each date and of the trajectories map for 2007 were assessed using 100 random points for each image, verified by visual interpretation of the Landsat images, of aerial pictures of 2001, of SPOT 5 images of 2005 (in true colors at 2.5 m of resolution), and field observations. Thirdly, a vegetation index calculated as the near infrared minus the red and short-wave infrared channels was used to analyze changes in vegetation density in forests except for the 1973–1975 images (see Freitas *et al.* 2005). For each date, we calculated the mean value and standard deviation of this vegetation index for all pixels classified as forest according to the land cover trajectories analysis in each village.

Surveying Local Environmental Cognitions

Field surveys combining interviews, group activities, guided visits in the forests and uplands, and collection of secondary data were conducted from December 2007 to February 2008. In total, 19 interviews with open-ended questions were conducted on a sample of people selected to maximize the socioeconomic and land uses diversity in each village[2] to assess: (i) familiarity and frequency of contacts with the forest, (ii) the uses and importance attributed to the forest, (iii) environmental features regarded as important for sustaining their livelihoods, (iv) attributes of a "good quality" forest, (v) ethnic knowledge and religious and importance of forest, (vi) dependency on forest for livelihoods, (vii) importance of different activities for livelihoods, and land use changes during the last 15 years, (viii) extent and quality of forests in the village at different periods (2007, 2003, 1993, 1978), (ix) causes of changes in forest extent and quality for the same periods, (x) perceptions of self-efficacy regarding management of forests and livelihoods, and (xi) forest management activities and conservation practices undertaken by the household and the village. This covered the perception (viii), interpretation ((ix) and (xi)), evaluation

[2] I.e., rich, poor and middle-class farmers; young, older and middle-aged; and farmers practicing upland and lowland agriculture, forestry and off-farm activities (Appendix 1).

((ii), (iii), (iv), (v), (vi) and (vii)) of forest changes, and perceived self-efficacy (x). These interviews also included the drawing of an individual mental map, representing the village and its key features, especially in the forest. In each village, we also first conducted discussions with two groups of 8–10 persons, selected to maximize the diversity of age, gender, socioeconomic status and land use practices, on the same topics as for the individual interviews. Each group was asked to clarify agreements and disagreements with the other group and among themselves. These discussions were critical to validate insights from individual interviews. Secondly, a participatory mapping of the village area was undertaken on a transparent sheet using a 1/10.000 scale color print of the 2005 SPOT 5 images. Participants indicated the land uses and land tenures, their perceived quality of forests and soils, location of specific events affecting the forests, and other remarkable features. Group discussions and individual cognitive maps were coded by theme to extract important and re-occurring features in discourses on forests and uplands. Several walks across the forests and uplands guided by local informants, and being hosted in villages, provided further opportunities for other informal interviews, discussions and observations.

Analysis of Land Use Practices, Policies and Socio-Economic Change

In addition to open-ended interviews, 45 semi-structured interviews with key informants, including farmers, forest protection rangers and various officials were conducted on the biophysical and human context, land use histories in the villages since the 1970s, and implementation of the different policies affecting land use. These interviews also enriched the study of environmental cognitions of civil servants, as well as their appraisal of the environmental cognitions and behaviors of other local agents. From the province, district, commune and village administrations, available land tenure, land use and land zoning maps were collected, as well as statistical data on socioeconomic characteristics and agricultural activities. All interviews and group discussions also included questions on household composition, and area, production and income for different crops and activities, including off-farm to assess the main socioeconomic attributes of the households. The participatory maps were digitized, allowing the measuring of the spatial distribution of different land uses and regulations as described by local agents.

Results

Participatory Maps of Land Use in 2007–2008

In Khang, from north to south, the western slope was separated into an area allocated to households and used mainly for afforestation; a hill used as community livestock grazing area; and an area described as the watershed and not allocated to households. In all villages, areas identified as "watersheds" were areas considered by local actors as the sources of the main water flows of the villages. The larger part of the eastern slope was allocated to households and set aside for forest regeneration. In Na Da, most of the land is uplands allocated to households, where shifting cultivation is allowed only on some areas classified as production forests. The north-western and eastern parts of the village were not allocated to households and were used respectively as community forest and community livestock grazing area. Bordering the two villages in the south is the Nam Xuan Lac preservation area, comprising karstic mountains unsuitable for agriculture, classified in 2004 as special-use forest. In Hoc, most of the western slope was allocated to households, with the largest area classified as forestry land and used for afforestation and a smaller area in the south being classified as land for agricultural production. The eastern slope is used as community forest to gather products and graze livestock. In Pa Dong, the northern hill is described as an area formerly cultivated and then set aside for forest regeneration, and the southern hill is the watershed forest of the village. The eastern part of the village is covered by hills used for agriculture and occasionally for afforestation.

Land Cover Change Analysis

For both series of images and the four dates, the estimated accuracies of the land cover classifications were high, as well as the discrimination among forests, shrubs and other land in the 2007 map of vegetation types (Meyfroidt 2009). Rapid deforestation occurred in Khang during the 1980s (Figs. 4a and 5a). In the early 1990s, only small scattered forest patches remained, covering 33 % of the village area, mostly on the steep slopes. The eastern slope of the river and the southernmost area were almost entirely deforested, and covered by crops or bare lands. Starting in the early 1990s, the deforestation decreased. Natural vegetation was restored on 71 % of the village area between 1993 and 2000, and most of it had grown into forest in 2007. The density of forests measured by the vegetation index declined then increased slightly between 1993 and 2007 (Fig. 6). Reforestation was particularly important in the southernmost, non-allocated land called the watershed area. In Na Da, deforestation was less rapid than in Khang between 1975 and 1993 (Figs. 4b and 5b). The western area, which became the community forest, was largely cleared, while the southern part close to what became the preservation area was still extensively forested. Between 1993 and 2000, both deforestation and natural vegetation recovery occurred, the latter mostly on the western area. In 2007, the forest transition appeared, with a net increase in forest area and a decrease in shrub area. Between 1993 and 2007, forest density declined slightly then increased (Fig. 6). In Hoc, between 1973 and

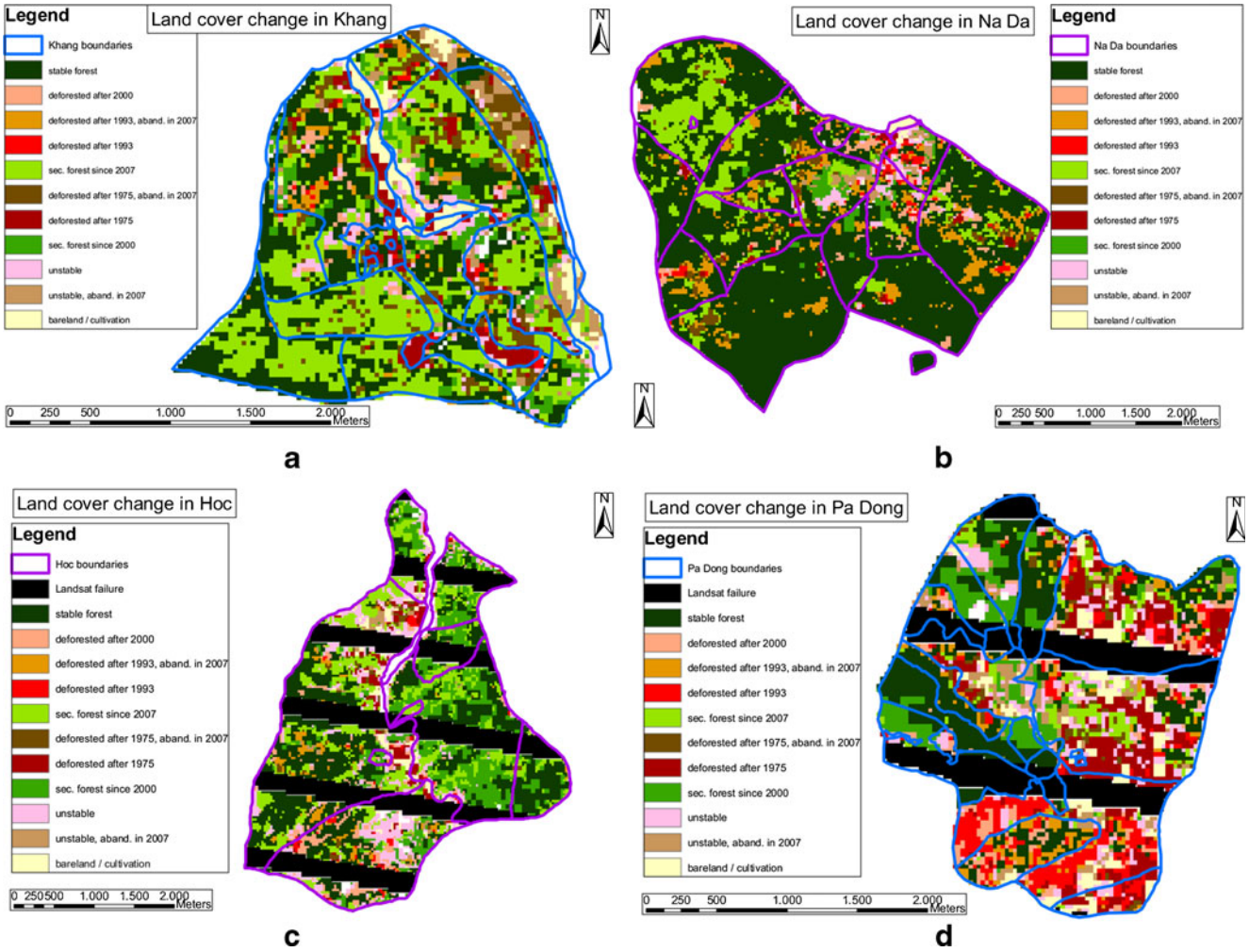

Fig. 4 Land cover trajectories 1975-2007 in Xuan Lac and Ta Hoc. **a** Khang. **b** Na Da. **c** Hoc. **d** Pa Dong. For Hoc and Pa Dong, gaps are present due to failures in the Landsat imagery system (Markham *et al.* 2004)

1993, clearing occurred mainly on the western slope, and vegetation recovered mainly on the eastern slope (Figs. 4c and 5c). Between 1993 and 1999 the shrubs and forest cover increased, mostly on the forestry area. During this period, the forest density index increased in the village, slightly in the community forest area and more importantly in the forestry area (Fig. 6). Between 1999 and 2007, forest area further increased, but density decreased strongly because of logging and fires (see below). In 2007, the community forest in Hoc was largely covered by an open mix of shrubs, bamboos and scattered trees. In Pa Dong, between 1973 and 1993, clearing occurred mostly on the agricultural land in the eastern area, and vegetation restoration on the two main forest areas (Figs. 4d and 5d). Between 1993 and 1999, forest and shrub areas slightly declined, mostly in the agricultural area and the limestone forest south of the village. Forest density declined in the watershed forest and increased in the regeneration forest (Fig. 6). Between 1999 and 2007, few land cover conversions occurred. Forest density declined overall, mainly in the eastern part of the watershed forest. In 2007, the watershed forest in Pa Dong was logged-over but some large trees still remained.

Land Use Changes

Khang

With the failures of cooperative agriculture and the progressive privatization of land (Castella and Quang 2002), shifting cultivation extended rapidly in the uplands of Khang during the 1980s. In the early 1990s, the deforestation decreased, degraded land was abandoned and vegetation started to regenerate naturally. The extent of shifting cultivation declined and agricultural intensification took place in the paddylands, first with the introduction of new seed varieties, fertilizers and generalization of double cropping. Paddy rice intensification initially reduced the labor available for upland cultivation (Meyfroidt and Lambin 2008b), as more weeding and care were required for the new varieties.

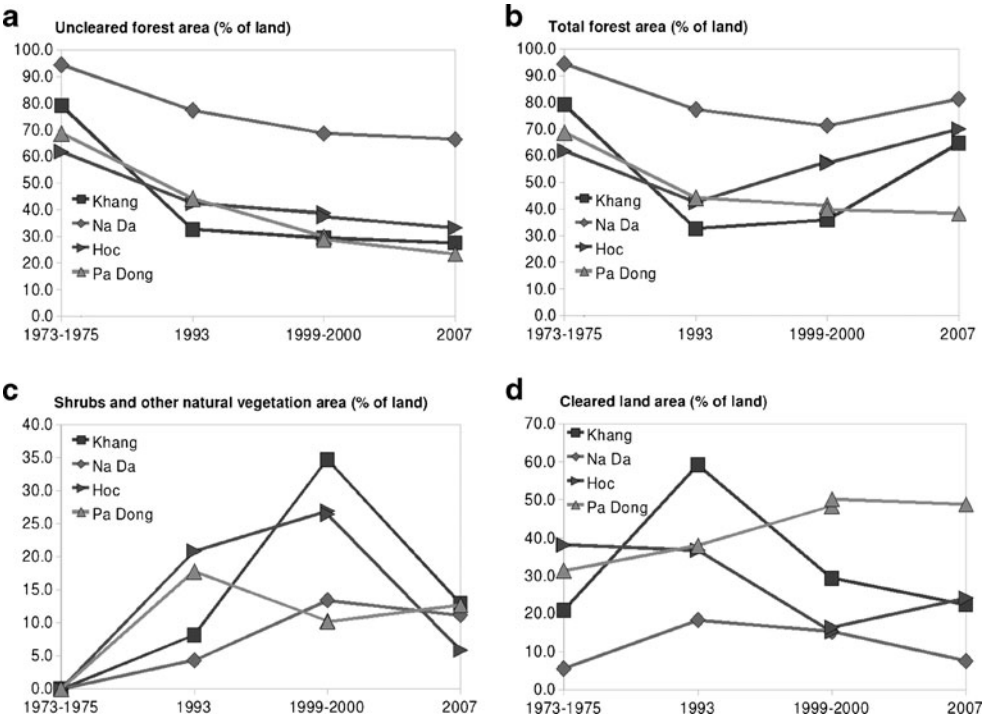

Fig. 5 Main land cover changes 1973/75-2007 in the four villages. **a** Uncleared forest area. **b** total forest area. **c** shrubs and other natural vegetation. **d** cleared land. For Hoc and Pa Dong, one curve represents the trajectory from 1973 to 1999, over the whole village. The second curve represents the trajectory between 1999 and 2007 but only for the area not disturbed by Landsat failure (Markham *et al.* 2004)

But labor requirements fell after the widespread use of herbicides began in the 2000s. In 2008, a number of households were still practicing shifting cultivation, but fewer than in the 1990s. Since 2005, forestry has become a more attractive activity (Sandewall *et al.* 2010). In 2007–2008, forestry land on the west bank was a mosaic of fallows, cassava and maize fields, and tree plantations, mainly "Xoan" (*Melia azedarach*), "Sua" (*Dalbergia tonkinensis*) and bamboos (*Neohouzeaua dullooa*), occasionally with food crops and young trees intercropped. After several floods in the 1990s, villagers initially reacted by cleaning up and making protective walls and ditches, and subsequently by ceasing cultivation in the upper part of the valley south of the village to mitigate floods. This area, identified as "watershed" on individual and group maps, is regarded as the primary water source for the main stream which irrigates paddy fields. In agreement with the commune authorities, villagers did not allocate this area to households, and around 1996 decided to set it aside to restore the stability of water supply. The watershed area was largely reforested, and in 2008 was covered by a regenerating forest dominated by "Bo de" (*Styrax tonkinensis*, a light-demanding pioneer species), with larger trees and more dense undergrowth than in the other regenerating areas. After the land allocation, the farmers agreed informally that the owner of a forest plot with important value for water flow should have stronger restrictions on tree cutting.

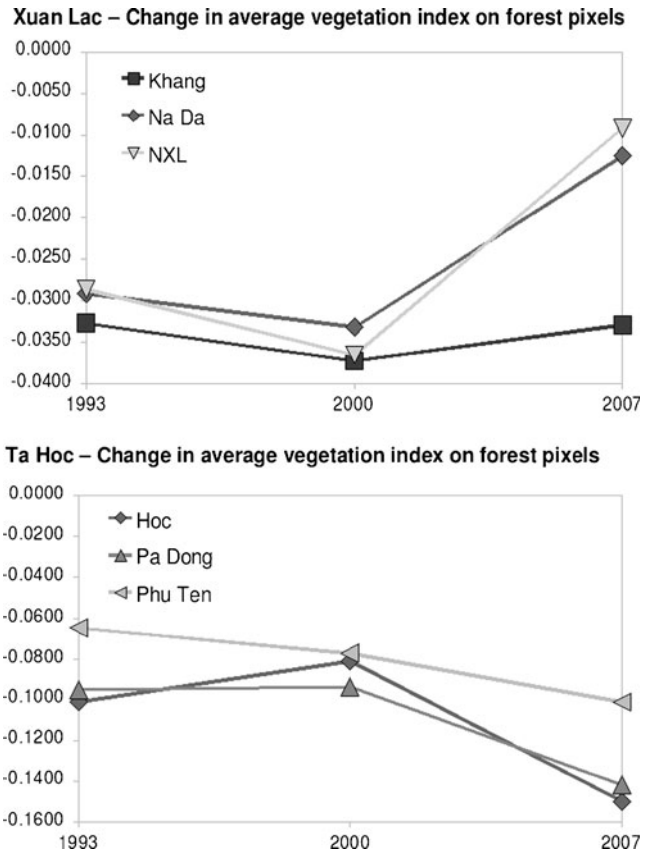

Fig. 6 Change in vegetation index on forest pixels 1993-2007. **a** Xuan Lac. **b** Ta Hoc. Benchmarks are given for comparison: NXL: the Nam Xuan Lac preservation area. Phu Ten: another village in Ta Hoc indicated as holding valuable timber resource

Na Da

Since the 1970s, fallows progressively shortened and length of continuous cultivation was increased in the uplands of Na

Da. In 1990, Tay families from a neighboring village claimed back the paddylands that they had contributed at the establishment of the cooperatives (Castella and Quang 2002). This initially increased reliance on shifting cultivation and induced the clearing of many new plots. The period 1991 to 1996 saw the maximum extent of cultivated lands, covering around 18.3 % of the village area (Fig. 5). Throughout the late 1990s and 2000s, continuing cultivation of degraded plots and regeneration of abandoned ones co-occurred. The potential maximum fallow length dropped from over 50 years in 1990 to around 14 years in 2007 due to increased population density alone, or around 4 years when policy restrictions on areas available for shifting cultivation are taken into account (i.e., land allocation, forestry land use zoning, and the preservation area) (see Meyfroidt 2009). Increasing length of continuous cultivation and shortening of fallows resulted in decline of yields and labor productivity and increase in the strenuousness of the work, in particular weeding (Husson *et al.* 2004; Stevoux 2000). For forest fallows under 20 years, yields dropped between the first and the fourth year of cultivation, and the decrease was more rapid for shorter fallows (Husson *et al.* 2004). Weeds presence was correlated to both fallow length and yields. Between the cooperative period and 2000, labor productivity of upland rice cultivation in typical Dao villages from Cho Don district, in Vietnam Dong (VND) of 1999–2000, declined from 32,000 VND/manday to 8,000 VND/manday (Castella *et al.* 2002; Fatoux *et al.* 2002). Meanwhile, as in Khang, labor requirements initially increased, but then with increased use of fertilizers, herbicides and new seed varieties, labor productivity of paddy rice increased from 20,000 VND/manday to 29,000 VND/manday (Castella *et al.* 2002; Fatoux *et al.* 2002). The relative profitability of shifting cultivation and paddy rice cultivation thus reversed.[3] Starting in the mid-1990s, the extent of cultivated land gradually decreased. Increasingly, farmers turned to paddy rice cultivation, building terraces where possible or by renting or acquiring fields in neighboring villages. Since 2003, a handful of households also generated considerable income from forestry, but in 2008 it remained a marginal activity. Many households had neither the capital nor the labor required for paddy rice cultivation or forestry, and continued shifting cultivation despite land degradation and various policies constraining their access in the uplands. Because a large forest area remained in the early 1990s and farmers had few alternative options, the decline in shifting cultivation was gradual and explained by farmers through a mix of "push and pull" effects (Table 3).

[3] Note that the decline in labor productivity with shortening fallow length observed here is not a universal feature of shifting cultivation systems (Nielsen *et al.* 2006), as shorter fallows require more labor for weeding but less for clearing the land (Conelly 1992).

Hoc

In Hoc, the steepness of the valley greatly limits the area suitable for irrigated rice cultivation. In the 1970s–1980s, maize, cassava and upland rice were cultivated on the east slope. In 1991, in an agreement between authorities and villagers, who did not regard the land as necessary for agriculture, the east slope was assigned for the protection of the watershed of the Hoa Binh dam downstream on the Da river. Agricultural activities were forbidden and collection of wood and forest products was restricted. Agricultural lands had been moved to the west slope, which was more productive with forests covering rich soils. During the 1990s, maize increasingly replaced rice and cassava on hillsides, following the introduction of high-yielding varieties and its increased use as fodder for livestock destined for urban markets (Saint-Macary *et al.* 2010; Sikor 2001; Sikor and Dao 2002). Forest regenerated on the community area, but was perceived as degraded and of poor quality. Although a forest protection group was formed in 1991, responsible for protecting community forests from fires, illegal logging and agriculture, villagers and commune officials consider the group as not being effective. Patrols in the forest are made by one member once or twice per month. When alerted, the group can extinguish small fires or apprehend intruders. But significant uncontrolled fires spread in 1996, 2002 and 2004. Villagers, commune officials and group members themselves agree that their commitment and effectiveness were low (Table 3).

Pa Dong

In the early 1970s Hmong families settled in an area covered by old growth forest, started cultivating maize, cassava and upland rice, and set aside the forest above the village as watershed. During the 1980s, selective logging affected this watershed and during the 1990s the villagers strengthened its protection. Every man in the Youth Union serves in the forest protection group for 5 years. At the time of fieldwork in 2007–2008, the group held a monthly meeting to review regulations and group performance. Forest was monitored daily and at night except during agricultural bottlenecks and a few other occasions. The group was frequently violently confronted by illegal loggers (Table 3). Commune officials and records confirmed that pressures from outsiders were strong because Pa Dong had some of the most valuable forests remaining in the area. Villagers and officials

Table 3 Representative quotes from the interviews and group discussions

On land use changes in Na Da	
"I gave up upland rice 2 years ago because I had to spend a lot of labor for weeding, and the yields were very low. The weeds grow again and again and we don't have a lot of labor."	Middle-class farmer in Na Da, interview n°55
"Anyway, I would have stopped shifting cultivation even without land allocation, because it was becoming very difficult, and I would have gone to make cultivation and other things in the lowlands just like I did. But without land allocation some other people would have taken my land and continued cultivation. A lot of households, maybe more than half of the village, lack of land seriously."	Rich farmer and head of Na Da village, transect walk in the community forest, interview n°52
About the forest protection groups in Hoc and Pa Dong	
"In Hoc the group is less effective [than in Pa Dong]. The area is larger, there are more fires, and the group is not very effective for managing wild fires. It is more difficult for them, but they are also less effective. They are not quick to detect fires, and not good to extinguish them."	Commune officer, Ta Hoc commune, interview n°6
"In this place [in the watershed forest] last year, during the night, we came face to face with illegal loggers. They were carrying logs with a buffalo. We had to fight with knifes and guns, and eventually they flew away, leaving their buffalo."	Young farmer, member of the forest protection group, interview n°27
"(…) Pa Dong people have a high awareness of the importance of protecting forests. The forest protection group there is strong and effective, they do that well by themselves. The group is more efficient in Pa Dong [than in Hoc], because there is a border with other communes and more valuable trees, so there are more burglars. The forest protection group has to be more effective, they make patrols at night."	Consensus from group interviews of several commune officials, Ta Hoc commune, interview n°6
On environmental cognitions	
In Khang	
"Until 1993, we did shifting cultivation to make a living, because we had no other option and the government had no solution. The worst period, with the highest deforestation, was 1984–1992. At that time there was a drive to cut the forests. It was like propaganda, but a bad propaganda."	Group discussion (subgroup 1), interview n°51
"We were exploiting the forests without restraint. Soils were exploited to make pioneer upland rice. Forests were seen as bringing no good value to the people, so nobody took care of it."	Group discussion (subgroup 1), interview n°51
"Slash and burn was everywhere, there was no forest left to destroy."	Group discussion (subgroup 2), interview n°51
"The land was dry; there was a scarcity of drinking water. At that time we recognized the changes in forests."	Middle-class farmer and policeman, interview n°48
"There were no forests anymore, erosion of the soils, the air wasn't fresh. Awareness started to increase as the people realized:'oh, we only have one or two trees left'."	Successful farmer, interview n°47
"Floods in 1996 occurred during five days. It was a big disaster, it destroyed everything. There were sands and rocks in the paddy fields."	Middle-class farmer, interview n°50
"In the mid-1990s there were big problems of floods and erosion. The paddy fields were flooded with soil and rocks; the water was brown. We stopped shifting cultivation for two reasons: first, there was no place to make it anymore, no more forests and the soils were exhausted. Second, we became aware of the benefits provided by forests, like water and p*rotection of paddy lands from floods and erosion."*	Consensus from the group discussion, interview n°51
In Na Da	
"[15 years ago] Soil erosion was terrible, the soil was very thin and the yields were very low. (…) You had to go further and further [to find suitable plots]."	Middle-class farmer in Na Da, interview n°60
"Forests must be protected so that everyone can have benefits from it. On my forest I want big and old trees to grow so that when they are good I can ask the permission to cut and sell. A good forest is one on which we can forbid people to come and cut freely, even myself. (…) In 1993 there was still a green forest cover but also at that time the people were making shifting cultivation and destroyed the forest everywhere. They were hungry and there was not enough food. (…) it was difficult to cultivate. When there were heavy rains, the soil was sliding on the village and on the paddy fields. There were even big trees falling down the mountain. We were afraid of heavy rains. But at that time I was happy of being able to cut the forest everywhere."	Middle-class farmer in Na Da, interview n°60

Table 3 (continued)

In Hoc	
"Forty years ago the forestry area was covered by primary forest. Thirty years ago there was already a decline but still a lot of huge trees and plenty of animals; 20 years ago there were big trees in the forest. Fifteen years ago we realized the changes in forest quality, but the degradation was continuous throughout the years. Ten years ago the change was becoming very clear; there were no huge trees anymore. At that time we started to take actions."	Consensus from the group discussion, interview n°21
In Pa Dong	
"The north side of the natural forest is protected from logging and agriculture, because it is the watershed area of the village. When Hmong go somewhere to start a village, if a place has agricultural lands but no water, they go elsewhere. Since the starting of the village the importance of forest for watershed is well understood. However, the interdiction is not complete. If villagers see trees suitable for their needs in the north side, they can ask permission to the village leader to cut them."	Rich farmer, former head of the village (1980–1985), interview n°25
"If people cut trees in the watershed forest, the penalty should be much more than jail, because when they do that they kill the village. Since the beginning of the village, it was forbidden to cut trees in the watershed area, but some people did it, the regulation was not so strict, and there was no fine. After 1996, we became very strict with the regulations, and we believe that the penalty should be higher than for the rest of the forest."	Young farmer, member of the forest protection group, interview n°27

Interviews numbers refer to Appendix 1

highly praised the forest protection group (Table 3). In some areas natural forest regeneration was assisted by the work of the local Youth Union and Mai Son district Forestry College.

Environmental Cognitions

Overview

Important environmental features related to forest or tree plantation mentioned in individual cognitive maps, interviews and group discussions (Tables 4 and 5) included water, timber, bamboos and non-timber forest products (NTFPs), protection from floods and other climate-related hazards, and plantation products. Many interviewees merged their answers to questions on the uses and importance of forest and the criteria for a good quality forest (Table 6). Throughout the text, "quality" — and by contrast, degradation — of the forest always refers to indicators described by local actors. A good quality forests is generally characterized by three main categories of indicators: management (e.g., protected from fire, livestock grazing and hunting); provision of services (e.g., humid, and rich soils, protection from erosion and floods, water); and aesthetics and wildness (e.g., numerous large trees, beautiful and dense green cover, wild animals, and rare species) (Table 6). Most causes of deforestation described involve activities of villagers, but a few people mentioned activities of outsiders and natural causes (Table 7). Underlying factors of forest changes mentioned included village-level features such as forest protection groups and custom regulations, opportunities and constraints induced by government policies and NGO programs, population growth, lack of paddyland, lack of forest, increased awareness of the role of forests and incentives provided by growing timber markets.

Khang

According to interviewees, in the 1970s the forests were very good quality with large and abundant trees, abundant water flows (enough to cultivate all the paddylands), good soil quality and a high diversity and quantity of large animals. In the 1980s deforestation was intense (Table 3), exacerbated by the unstable political context (see below). In the early 1990s, people progressively became aware of landscape degradation, and deforestation decreased because of the scarcity of remaining forests (Table 3). In the mid-1990s (in particular 1996) several floods seriously damaged paddy fields (Bergeret 2002). Farmers and officials attributed these to deforestation and the consequent loss of water regulation and soil protection functions, and perceived them as catastrophic given the importance of paddy rice. People also perceived important problems of scarcity and quality of

water for drinking and paddy irrigation, and according to the farmers, recognition of these problems was critical in raising motivation to preserve forests (Table 3). The upstream and southernmost part of the valley is identified as "watershed" on individual and group maps, and is regarded as the primary source for the stream irrigating paddy fields. In 2008, farmers considered this area to have the highest quality forest and soils for agriculture. Smaller streams flowing from the forest were also regarded as very important for drinking water, and were mentioned on the individual and group maps. Overall, forests were considered to be the highest quality 30 years ago. Satisfaction with forest quality was lowest in 1993, then improved until 2008.

Na Da

Villagers explained that in the 1970s the forest was good, with large trees and rare species like "Dinh" (*Markhamia stipulata* (Wall) Schum) and "Tram huong" (*Aquilaria crassna* Pierre), and many large animals. However, it was poorly protected and people cut trees and hunted freely. The early 1990s was a turning point, with a mix of devastation and forest remnants with huge trees and rich soils. By the mid-1990s soils were exhausted (Table 3). Yet, a lack of alternatives for many households meant the decline in shifting cultivation was gradual. Floods also occurred in the mid-1990s, including the major event of 1996. Compared to Khang, farmers in Na Da were less dependent on paddy fields for their subsistence needs, but because of their scarcity and the difficulty to obtain them, paddy fields were highly valued. Farmers explained that floods and erosion were decisive factors in making them aware of the adverse effects of deforestation. In the longer term, these events contributed to their valuation of a stable and restored forest and the necessity of regulations and constraints. Many people had mixed feelings about both the period of free cultivation and current regulations. On the one hand they valued forest protection more than in the past, but on the other hand they suffered from restrictions on shifting cultivation (Table 3). Satisfaction with forest quality was lowest in 2003, but in 2008 quality was ranked similar to 1993.

Hoc

In the 1970s the forests were described as vast and with large trees, but were then cleared for agriculture mainly on the eastern slope. Forest regenerated there after it had been fallowed, but remained degraded and of poor quality. Villagers pointed to several factors contributing to forest degradation: population growth in the early 1990s, increasing the demand for construction wood at a time when harvesting regulations for forest products were not strongly enforced; illegal loggers from neighboring villages and cultivators starting uncontrolled fires. During the 1990s and 2000s, villagers became gradually aware of the decline of forests and their importance. During the interviews and group discussions, they expressed conflicting views about the timing of forest changes and their perceptions of forest degradation. Some highlighted the abandonment of agriculture on the community area in the early 1990s and subsequent regeneration, others argued that at that time logging and fires were already degrading the forest. After discussing vigorously, they finally agreed that in 2007 their community forest was highly degraded and still degrading, but their commitment to forest protection was low. Satisfaction about the forest quality declined continuously from 1978 until 2008 (Table 3).

Table 4 Summary of cognitive maps by individuals

	Khang	Na Da	Hoc	Pa Dong
Nb of maps	5	5	4	4
Proportion of maps indicating different features				
Water/stream	1.00	0.00	0.25	0.75
Water/stream from forest for agriculture	0.00	0.00	0.75	0.75
Water/stream from forest for households	0.00	0.60	0.50	0.25
Upland cultivation/quality of land for agriculture	0.00	0.00	0.25	0.75
Forestry/tree plantation	0.20	0.40	0.50	0.75
NTFPs/natural forest quality	0.20	0.40	0.50	0.25
Livestock grazing	0.00	0.20	0.50	1.00
Sizes				
Settlements	2.7	3.1	1.4	3.1
Paddylands	0.0	no	2.0	2.0
Forest — allocated regeneration	no	no	3.8	4.6
Forest — community regeneration	3.5	1.6	1.5	1.6
Forest — community watershed	no	3.3	3.0	0.3
Forest — plantation : forestry	2.2	0.2	2.5	1.3
Forest — upland cultivation	no	no	0.8	0.9
Forest — livestock	no	0.3	1.1	1.9
Upland cultivation not forest	3.0	2.6	no	no
Mine	no	no	1.7	no
Nam Xuan Lac preservation area	no	no	2.5	2.5

Sizes are ranked from 1: very small to 5: very large

Pa Dong

Setting aside the forests above the village at its establishment was explained as part of traditional Hmong land management (Table 3). Stable water flows from the forest were emphasized by interviewees and individual maps as one of

the most important indicators of the quality and value of a forest and a sustainable environment (Table 4). Selective logging was unambiguously regarded as the cause of the continuing perturbation of water flows during the 1980s. During the 1990s, when it became critical, villagers strengthened their commitments to protect the watershed forest. As in Hoc, satisfaction with forest quality declined continuously from 1978 until 2008.

Discussion

Land Use Changes and Exogenous Socioeconomic Factors

The main land use, socioeconomic and political changes in the four villages were consistent with other accounts of recent rural changes in the mountains of Vietnam (Meyfroidt and Lambin 2008b). In the northeast, studies described the deforestation in the 1980s linked to the failure of cooperative agriculture and unstable political context; the intensification of paddy rice cultivation; a shift of labor from hillsides to paddyland; and marginalization of Dao villages such as Na Da following the loss of access to paddylands (Castella and Quang 2002; Mellac 2000). Although continuing deforestation in Dao villages during the 1990s was observed, our data show that in the 2000s Na Da underwent a reversal of forest cover trend. Other studies described the shift from upland rice for subsistence to maize grown for markets on permanent fields in the northwest (Saint-Macary *et al.* 2010; Sikor 2001; Sikor and Dao 2002), and the establishment of forest protection groups by the authorities of Son La province (Sikor 2004). The forest transition in Vietnam was due to a combination of economic and political responses to forest and land scarcity, economic changes, and market integration (Meyfroidt and Lambin 2008b). Several factors, including the allocation of forestry land to households, land zoning, new forest management practices, and food crop intensification combined in "push and pull" effects to decrease the footprint of agriculture on hillsides. Reforestation was also supported by policies restricting wood exploitation in natural forests and banning exports of raw wood products (Meyfroidt and Lambin 2009). The land use histories of these villages reflect the influence of these factors, and are consistent with the main features of smallholder agricultural intensification path leading to forest transition in Vietnam (Meyfroidt and Lambin 2008b).

Table 5 Summary of interviews and group discussions — important features in the environment

Commune	Xuan Lac				Ta Hoc			
Village	Khang		Na Da		Hoc		Pa Dong	
Proportion of respondents mentioning different themes or presence/absence of the theme in the group discussion	Ind.	Group	Ind.	Group	Ind.	Group	Ind.	Group
What is important in your environment?								
Non forest-related								
upland agriculture	0.33	1.00	0.60	1.00	1.00	1.00	0.75	1.00
livestock	0.33	1.00	0.60	1.00	0.75	1.00	0.75	1.00
paddy rice	0.67	0.00	0.60	1.00	0.25	1.00	0.00	0.00
transportation	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
clean water	0.00	1.00	0.00	0.00	0.00	1.00	0.75	1.00
financial capacity	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
health	0.00	0.00	0.00	0.00	0.00	1.00	0.25	0.00
fishponds	0.33	1.00	0.00	0.00	0.00	0.00	0.25	1.00
good seeds	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest-related								
water from the forest	0.00	1.00	0.20	0.00	0.00	0.00	0.50	0.00
forest to protect from floods, typhoons, droughts	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
home gardens and fruit trees	0.00	1.00	0.00	1.00	0.00	0.00	0.50	1.00
bamboo	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
forest for timber wood (including plantation)	0.67	0.00	0.80	1.00	0.00	0.00	0.00	0.00
forest for ntfps	0.00	0.00	0.20	1.00	0.00	0.00	0.00	0.00

Presence/absence of a theme in group discussions are respectively indicated as 1/0

Table 6 Summary of interviews and group discussions — uses, importance and criteria of quality of forests

Commune	Xuan Lac				Ta Hoc			
Village	Khang		Na Da		Khang		Na Da	
Proportion of respondents mentioning different themes or presence/absence of the theme in the group discussion	Ind.	Group	Ind.	Group	Ind.	Group	Ind.	Group
Uses and importance of forests/uplands — What makes a good quality forest?								
Products gathering and activities								
upland agriculture	0.67	1.00	0.60	1.00	0.25	1.00	0.00	0.00
livestock grazing	0.67	1.00	1.00	0.00	0.75	0.00	0.50	0.00
ntfps (including bamboo shoots)	0.33	1.00	0.80	1.00	0.75	1.00	0.00	1.00
timber wood for household uses	0.67	1.00	0.20	1.00	0.75	1.00	1.00	1.00
timber wood for selling	1.00	1.00	0.60	1.00	0.00	0.00	0.00	0.00
bamboo (stems)	0.33	1.00	0.60	1.00	0.75	1.00	0.75	1.00
fuelwood	0.33	1.00	0.40	1.00	0.00	1.00	0.75	1.00
hunting	0.33	0.00	0.00	0.00	0.00	1.00	0.00	0.00
mineral resources	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Management								
no fire	0.00	0.00	0.00	0.00	0.50	1.00	0.00	1.00
no livestock grazing	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00
no unmanaged/illegal cutting	0.00	0.00	0.80	0.00	0.50	1.00	0.25	0.00
no hunting	0.00	0.00	0.00	0.00	0.25	1.00	0.00	0.00
well protected from harmful activities	0.67	0.00	0.60	1.00	0.25	1.00	0.50	1.00
grass and vines under the trees are cut to help regeneration	0.00	0.00	0.00	0.00	0.00	0.00	0.25	1.00
well-managed and improved by its owner (including plantations)	0.33	0.00	0.60	1.00	0.00	0.00	0.00	1.00
Services of the forest								
soils are humid	0.00	0.00	0.00	0.00	0.25	0.00	0.50	0.00
soils are rich/fertile	0.33	1.00	0.20	1.00	0.00	0.00	0.75	1.00
soils are protected from erosion	0.67	0.00	0.00	1.00	0.00	0.00	0.25	1.00
make a cool environment	0.00	0.00	0.00	1.00	0.00	0.00	0.25	1.00
protect paddyland from erosion, floods and mud flows	0.67	1.00	0.00	1.00	0.00	0.00	0.00	0.00
provide water	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
Naturalness of the forest								
forests make a green cover, are beautiful	0.00	0.00	0.60	1.00	0.00	1.00	0.00	0.00
many big trees, different kinds	0.67	1.00	1.00	1.00	0.50	1.00	0.50	1.00
many kinds of wild animals	0.33	1.00	0.60	0.00	0.00	1.00	0.50	1.00
forest is a primary forest	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00
Sustainability								
natural forests cannot be replaced because land is limited	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00
forest regenerates for the needs of future generations	0.33	0.00	0.00	0.00	0.00	0.00	0.50	1.00

Presence/absence of a theme in group discussions are respectively indicated as 1/0

Role of Environmental Cognitions in the Social-Ecological Feedbacks

Perception

Early detection of forest degradation played an important role in the contrasting trajectories of Hoc and Pa Dong (Table 8). In Hoc, when the community forest was set aside in 1991, the combination of agricultural abandonment and vegetation regrowth with demand for timber, recurrent fires and weak regulations led to a gradual degradation initially difficult to perceive, as manifested by the disagreements among the villagers. The decline in forest area before 1993 was slower than in other villages

Table 7 Summary of interviews and group discussions — forests changes and their causes

Commune	Xuan Lac				Ta Hoc			
Village	Khang		Na Da		Hoc		Pa Dong	
Proportion of respondents mentioning different themes or presence/absence of the theme in the group discussion	Ind.	Group	Ind.	Group	Ind.	Group	Ind.	Group
Quantity and quality of the village's forests[a]								
In 2008	2.00	2.00	1.60	1.50	0.00	0.00	0.50	0.00
In 2003	1.00	1.00	1.00	1.50	1.00	[b]	1.25	1.00
In 1993	0.00	0.00	1.40	1.50	2.00	2.00	1.75	2.00
In 1978	3.00	3.00	3.00	3.00	3.00	[b]	3.00	3.00
Direct causes of forest changes in the village								
Extraction/production activities								
agricultural production	1.00	1.00	0.75	1.00	0.00	1.00	0.50	1.00
fires	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
livestock grazing	0.00	0.00	0.75	0.00	0.50	0.00	0.00	0.00
fuelwood	0.00	0.00	0.00	0.00	0.25	0.00	0.25	0.00
timber/bamboo harvesting (houses)	0.00	0.00	0.25	0.00	1.00	1.00	0.75	1.00
hunting (and its forbiddance)	0.00	0.00	0.25	0.00	0.00	0.00	0.50	0.00
forest plantation activities	1.00	0.00	0.00	1.00	0.00	1.00	0.00	1.00
Outsiders								
illegal logging from outsiders	0.00	0.00	0.50	0.00	0.00	0.00	0.75	1.00
agricultural encroachment by outsiders	0.00	0.00	0.00	0.00	0.00	0.00	0.25	1.00
Natural causes								
natural hazards	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
natural regeneration	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00
Underlying causes of forest changes in the village								
Collective organization of the village								
village regulations and their enforcement	0.00	0.00	0.25	1.00	0.25	1.00	0.25	1.00
forest protection group	0.00	0.00	0.50	1.00	0.50	1.00	0.50	1.00
Policies and government/NGO activities								
land use planning	0.00	0.00	0.25	1.00	0.50	0.00	0.25	0.00
land allocation restrictions	1.00	0.00	0.25	0.00	0.50	1.00	0.00	1.00
land allocation increased awareness of benefits and responsibilities	1.00	1.00	0.25	1.00	0.00	0.00	0.00	0.00
reforestation programs	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00
awareness increased because of propaganda	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Other								
population growth	0.00	0.00	0.00	1.00	0.00	1.00	0.75	1.00
loss/lack of paddyland	0.00	0.00	0.50	1.00	0.00	0.00	0.00	0.00
forest disappearance left nothing more to cut	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
forest disappearance increased the awareness of the importance of forests, a.o. for mud flows protection and regulation of water supply	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
timber markets provided incentives	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00

Presence/absence of a theme in group discussions are respectively indicated as 1/0

[a] Overall quantity and quality of forests is ranked from 0: the worst to 3: the best

[b] No responses

(Fig. 5b), and after 1993 the combination of increase in forest area and decrease in forest quality may also have contributed to ambiguous perceptions. By contrast, in Pa Dong, Hmong traditional ecological knowledge and practice of setting aside the upper part of the hill as a watershed forest (Corlin 2004; Vuong 2004) allowed them to monitor water supply from the forest, thus increasing the saliency of forest degradation.

Table 8 Summary of main environmental cognitions and forest outcomes by village

	Khang	Na Da	Hoc	Pa Dong
Explanatory variables				
Sources of information about the forests	Multiple uses, daily visits, long-term familiarity with the place, some government propaganda	Multiple uses, daily visits, long-term familiarity with the place, important gathering activities, external markets, important government and NGO propaganda	Multiple uses, daily visits, long-term familiarity with the place, a few government propaganda	Multiple uses, daily visits, long-term familiarity with the place, government propaganda, collaboration with forestry college
Early detection and recognition of environmental change	No, because of very rapid changes	No, because of very rapid changes	No, because of slow trend of degradation	Yes, because of traditional focus on watershed forest
Attribution of changes to natural/anthropogenic causes	Mainly anthropogenic, but also natural regeneration of forest	Mainly anthropogenic, but also natural regeneration of forest	Mainly anthropogenic but also an emphasis on natural hazards, including typhoons and fires	Mainly anthropogenic, but mostly from outsiders
Valuation of the resources and its changes	High because of catastrophic events and effects on paddyland	Moderate to high because of catastrophic events and effects on paddyland	Low because substitutability of timber and eventually because of the highly degraded state	High because of water scarcity in the village
Perceived possibility to predict, control and improve the future state of resources	High: (i) strong perception of self-efficacy on allocated land and (ii) important social capital for common land	Moderate: (i) few alternatives to shifting cultivation but (ii) strong emulation of successful leaders/pioneers in forestry	Low: (i) highly degraded resource which can hardly be improved, (ii) low confidence in the forest protection group, and (iii) several unsuccessful reforestation programs	Moderate: (i) strong perception of collective efficacy, (ii) important external pressures, and (iii) knowledge of assisted forest regeneration
Outcomes				
Sustained transition in forest area	Yes, with turning point in early 1990s	Yes, with turning point around 2000	Yes, turning point in early 1990s	No, but stabilization around 2000
Sustained transition in forest density/structure	Yes, with turning point around 2000	Yes, with turning point around 2000	No	No
Turnaround in satisfaction of forests by local actors	Yes, although fewer large trees remain than in the early 1990s	Yes, although fewer large trees remain than in the early 1990s, and uses of the forests are restricted	No, continuing degradation	No in overall: continuing degradation, but increasing satisfaction about the collective efficacy

Interpretation

Deforestation and forest degradation were generally attributed to human causes (Table 8). External actors were sometimes blamed, but given the political sensitivity and legal consequences of deforestation and logging, this cannot be used to draw meaningful conclusions, excepted for Pa Dong where external pressures are confirmed by other sources. In Hoc, forest degradation was attributed to logging but also to fires, considered very difficult to control. In Pa Dong, Hmong cultural knowledge allowed for causally attributing the perturbation and decrease in water supply to forest degradation, although scarcity probably arose partly from increasing population. In Khang and Na Da, rapid forest changes were salient and their attribution to human activity unambiguous. Floods and especially mud flows were primarily attributed to human-induced deforestation for shifting cultivation; therefore structural responses — beyond emergency responses after floods — were linked to land uses. Shifting cultivation has long been blamed for deforestation and environmental degradation in the mountains of Southeast Asia, through policies and public media efforts (Fox *et al.* 2009; Rambo and Jamieson 2003; Sowerwine 2004). As a result, upland residents have internalized perceptions of shifting cultivation and traditional agricultural practices as destructive and backwards, without necessarily having a clear understanding of the rationales underlying these claims, nor agreeing with them (Rambo and Jamieson 2003; see also Schad *et al.* 2011). During interviews, specific statements referring to concrete examples and locations relating to floods and the role of upland deforestation, contrasting with more general statements referring to government propaganda, suggest that although public discourses likely contributed to the attribution of floods to upland cultivation, local direct experiences were more influential especially in the evaluation of the floods. This illustrates the social learning process where local and direct sources of ecological knowledge interact with external sources, such as government propaganda or projects from the nearby forestry college in Pa Dong (Table 8; see Meyfroidt 2011; Muchagata and Brown 2000; Reed *et al.* 2010).

Evaluation

In Khang, rapid deforestation and resulting barren landscape led to growing concerns about water-related problems and threats to the paddylands, illustrated by the dramatic memories of floods (Table 8). The high value attributed to the positive role played by forest for watershed protection by villagers was confirmed independently during a participatory ranking of forest-related priorities, part of the preparatory survey before the establishment of the Nam Xuan Lac preservation area in 2004 (PARC Project/FPD Bac Kan 2004). However, water-related problems provided the motivation but not the capacity to collectively restrict upland cultivation. Only when the forestland allocation policy was implemented did villagers set the watershed area aside and agreed on rules for managing plots deemed critical for water regulation. Thus, by increasing the commitment to forest protection, awareness derived from valuation of forests also facilitated the acceptance of land allocation and land zoning policies. In Na Da, a similar evaluation of threats to the paddylands was made, but fewer alternatives to shifting cultivation existed. Thus the watershed upstream of the paddylands was allocated to households, some of which still cultivated there in 2007–2008. The place reserved as community forest was a more distant, less productive area. In Pa Dong, the critical importance and non-substitutability of drinking water, and alleged links between water scarcity and forest degradation prompted the villagers to use the forest protection group — originally established by external authorities — to reactivate and enforce traditional forest protection rules focusing exclusively on the watershed. Villagers, commune officials and registers of apprehended intruders consistently confirm that illegal logging is mainly caused by outsiders, and that these measures were effective in containing degradation in the watershed forest. By contrast, degradation was undervalued in Hoc. Decrease in wood supply was not a concern because it was initially made up by imports from neighboring villages. Harvesting times of NTFPs slowly increased but availability was less affected. Villagers had no other incentive to protect the forest, as water availability did not depend on the forest and payments for watershed protection were low and not performance-based. When forest degradation eventually became salient, a positive feedback loop prevented the villagers from reacting: exhaustion of the main resource, timber, created disincentives for sound management and thus reinforced the degradation.

Self-efficacy

In Hoc in 2007, even though villagers were concerned about timber scarcity, also increasing in neighboring villages, and recognized that better management of the community forest might have secured larger timber resources (Table 8), the efforts needed to restore the timber supply seemed too great, and forest protection and management thus useless. Commitment to protect the forest was low and few believed that forest quality could really be improved.

Alternative Hypotheses

Exogenous socioeconomic and policy factors providing alternative hypotheses to explain observed land changes need to be assessed. Deagrarianization dynamics and development of various forms of off-farm activities are important forces of land use changes and decline in shifting cultivation in contemporary

Southeast Asia (Rigg 2006; van Vliet *et al.* 2012). Migration to employment centers and to the Central Highlands colonization area have increased in Vietnam over the recent decades (Phan and Coxhead 2010), and might have partly contributed to the forest transition at national scale (Meyfroidt and Lambin 2008b). But socioeconomic surveys during interviews and group activities showed average shares of off-farm activities in total household income ranging between 3 and 14 % across villages, the highest percentages being in Khang. Almost all interviewees ranked off-farm activities, outmigration and remittances as either non-existent or of very low importance, except for a few jobs in the commune administration, while agricultural activities were ranked very high. These rough measures, associated with qualitative evidence, suggest that, largely because of their remoteness, livelihoods in these villages remain strongly rooted in agriculture and land-based activities. Following the generalized typology of agrarian transition in Southeast Asia proposed by Rigg (2005), the four villages corresponded to type 2 "semisubsistence," combining subsistence with commercially oriented agriculture in village-focused livelihoods, as expected given our selection criteria.

In Khang, continuing reforestation of the watershed area could not be explained simply by sense of responsibility of households for their land, as this area was not allocated to households. Labor requirements dropped in the paddy fields with herbicides use in the 2000s, and a number of households still practiced shifting cultivation in 2007–2008. Furthermore, farmers agreed that the watershed forest held the most suitable agricultural soils of the village. Yet, households that continue shifting cultivation on non-allocated land were cultivating an area further from the village with poorer soils. Land degradation, land allocation, or lack of labor or interest could therefore not explain the absence of shifting cultivation in the watershed. In Hoc, alternative factors could not explain the continuing forest degradation: elders confirmed that Black Thai's ecological knowledge includes a land classification system reserving some forests for timber provision (Cam Trong 2007), and remote sensing confirmed the absence of agricultural encroachment. In Pa Dong, the role of water preservation appears central to the commitment to forest protection. Payments for forest protection were low and not performance-based. The small wood amounts required for traditional Hmong houses provided insufficient motivation for timber protection. By contrast, in Na Da, the perception of environmental degradation was less influential in land use changes. The combination of policy restrictions and declining returns on shifting cultivation provide robust explanations of the gradual abandonment of upland fields and subsequent forest regeneration. Farmers interviewed stressed the increased time and energy needed for weeding more than decline in yields.[4]

[4] Weeding is indeed often regarded as the most difficult taks in shifting cultivation, see Mertz *et al.* 2008, Pandey and Dang 1998.

With a shortage of paddyland, forestry becoming profitable only after 2003 and with highly restricted quotas, and few other opportunities, alternative activities did not fully compensate for the decline in shifting cultivation and cannot explain it entirely. The decline in shifting cultivation was mainly due to a negative ecological feedback from land degradation arising from shortening fallows and increasing length of continuous cultivation, themselves caused by increasing land scarcity mostly created exogenously by land zoning and allocation policies — as in other cases in Southeast Asia (Lestrelin and Giordano 2007, Fox *et al.* 2009) —, and by growing population. Even absent any policies, land scarcity might have been significant enough to seriously hinder shifting cultivation. In the poor soils of the area, short fallows coupled with buffalo grazing might be insufficient to maintain the productivity of upland rice with unchanged agricultural practices (Husson *et al.* 2004; Nikolic *et al.* 2008).

Outcomes of the Land Use Changes for the Environment and Livelihoods

Cognitive and motivational factors influenced the outcomes in the three response variables — transition in forest area, forest density, and satisfaction about forest quality (Table 8) — but were neither necessary nor sufficient to observe a transition in forest area, as exemplified by Hoc where forest area increased despite the relative absence of reinforcing cognitive and motivational components. In an intermediate way between exogenously imposed transition and endogenous responses (Lambin and Meyfroidt 2010), policies were also sometimes used as triggers to change land use systems and common pool resources management. Forest transition can occur with or without a similar transition in forest quality and satisfaction of local actors. People in the four villages were much more concerned about forest density, richness in large trees, animals and NTFPs, and the provision of services — usually perceived to depend on specific types of forest such as dense natural forest with large trees for water and timber, and mosaics of various vegetation types for NTFPs — than about forest area, which was thus a poor indicator. Furthermore, as the land use changes were partly imposed by policies, farmers often had ambivalent appreciations of the forest recovery (Table 3).

Conclusion: Conditions for a Feedback from Forest Scarcity on Land Use Changes

To see if some of the residual variance in forest changes could be explained by environmental cognitions, the villages were selected to avoid the most obvious causes

of reforestation already shown in previous studies. But as the main political and socioeconomic processes that affected the Vietnamese uplands in the last decades did occur in the study villages, they are thus representative of typical northern mountains villages. With regards to environmental cognitions, aspects linked to governmental discourses — e.g. the attribution of floods to shifting cultivation — can be widespread beyond the four villages (see Schad *et al.* 2011). Beyond, these cases might be representative of the possible roles of environmental cognitions under certain contexts.

These case studies showed how, under certain conditions, dramatic events or progressively increasing scarcity modified the perception, interpretation and evaluation of changes in forests. Cognitive appraisals of changes environmental services and products provided by forests, such as scarcity of timber or water, soil erosion and mud flows, whether or not actually caused by forest loss, did subsequently feedback on decisions and land uses (Marshall *et al.* 2005). In Khang, convincing arguments favor the hypothesis that villagers supported the reforestation of the watershed area because of the connection made between deforestation and water-related problems. By increasing commitment to forest protection, these problems also contributed to the acceptance of land allocation and land use zoning policies and to prevent the resumption of shifting cultivation in areas regarded as vulnerable and ecologically important. Gradual degradation, as in Hoc, was less likely than catastrophic events to trigger actions to preserve forests, because of (i) the difficulty of detection and recollection of slow changes (cf. the "shifting baselines", Dayton *et al.* 1998; and "environmental amnesia", Kahn *et al.* 2009; see Meyfroidt 2011), and (ii) the possibility of progressive substitution of the degraded resource or adaptation to its changing availability. This created a positive feedback loop of continuing degradation. In Pa Dong, forest degradation has been contained by active involvement of villagers rooted in their traditional ecological knowledge, which provided an initial valuation of forest for water provision, awareness of the importance of monitoring water resources, a causal attribution of declining forest quality for the decrease in water supply, and grounds for sanctions. The cases of Hoc and Pa Dong illustrate direct feedbacks where change in fundamental attitudes and beliefs of the agents is unnecessary to explain land use changes (Meyfroidt 2011; Reed *et al.* 2010). Khang is more representative of an indirect (or "transformative") feedback (Meyfroidt 2011; Reed *et al.* 2010) where environmental degradation modified the beliefs and attitudes of the actors. In Na Da, the change in attitudes was less influential in land use changes. This case is representative of a negative feedback from resource limitation (Lambin and Meyfroidt 2010).

Forest degradation, strengthening of forest and land zoning policies, discouragement of shifting cultivation as well as forest transitions have occurred in other countries of South and Southeast Asia (Meyfroidt and Lambin 2011; van Vliet *et al.* 2012), with various ways of involving and influencing environmental cognitions of local actors. For example, in Bhutan, participation of local actors and preservation of local cultures and traditions were emphasized (Uddin *et al.* 2007). How these different policy approaches impacted environmental cognitions and their roles in land changes deserve further studies.

The data presented here have shown that forest scarcity or degradation (see Rudel *et al.* 2005, Meyfroidt and Lambin 2011) had to be perceived, interpreted and evaluated before inducing a possible feedback on the land use practices of local actors and a forest transition. These steps constitute necessary but not sufficient conditions for environmental degradation to influence behaviors. Exogenous socioeconomic and policy processes were the main factors of the forest transition, but environmental cognitions did in some cases affect reforestation patterns (as in Khang), or forest density through the commitment of villagers to preserve forests (as in Pa Dong and Hoc, with different outcomes). Transitions in forest area, density and turnarounds in satisfaction levels and livelihoods of villagers are linked, but can evolve in different directions. The overall effects of forest transition on livelihoods of villagers were mixed. The trajectories in the four villages preclude extrapolation of the results throughout Vietnam, but show that in each place the interplay between broad socioeconomic and policy forces and local social-ecological peculiarities produce specific outcomes, yet sharing some similarities. Further studies should improve quantitative measures of changes in ecosystem services, in environmental cognitions and in land use practices to test more rigorously the role of environmental cognitions in social-ecological feedbacks. This should allow understanding and internalizing feedbacks in social-ecological systems (Turner *et al.* 2007).

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Appendix 1

Table 9 List of Interviews, December 2007–February 2008; structured and semi-structured interviews with mainly open-ended questions, and group discussions

Interview n°	Gender	Age	Context	Status	Topics
Ta Hoc commune and regional perspective					
1	M	? 40–50	In his office, at the North West Forest Science and Production Center office	Director of NorthWest Forest Science and Production Center	Patterns of forest changes in the region and forest policies
2	M	? >50	In his office, at Son La DARD, Son La town	Vice-director of Son La Department of Agriculture and Rural Development (DARD) and director of forestry department	Patterns of forest changes in the region and forest policies
3	M	? 40–50	At his home, with his family, in Chieng Ban	Rich farmer, chairman of Chieng Ban commune farmer's association	Agricultural changes and reforestation in the region
4	M	? 40–50	At his home, with his family, in Chieng Ban	Rich farmer from Sang village in Chieng Ban commune	Agricultural changes and reforestation in the region
5	M	? 30–40	At Mai Son district DARD, Hat Lot town	Forest protection ranger in Ta Hoc	Forest changes, illegal activities, forest policies
6	M, F	? 30–50	At Ta Hoc People's Committee building, Hoc village	Several group interviews with (i) the chairman of Ta Hoc commune's People Committee (PC), (ii) the land manager of the commune, (iii) the chairman of local Communist Party (CP) and former chairman of PC in 1995, (iv) the chair of women union, and (v) the chairman of farmer's association.	Livelihoods, agriculture and forest changes, forest policies, land allocation, reforestation programs
7	M	? >50	At his home, Pa Dongvillage	Rich farmer, vice-chairman of PC	Land use changes, and specifically the role of biophysical differences between Hoc and Pa Dong
8	M	? 40–50	At Ta Hoc PC building, Hoc village	Chairman of CP, former chairman of PC	Forest and land use regulations
9	M	? 30–40	At Ta Hoc PC building, Hoc village	Commune officer	Socio-economic changes
Hoc					
Key informants					
10	M	49	At his home, Hoc village	Rich farmer, vice-head of village	General topics, land use changes, policies, and reforestation programs
11	M	28	At his home, Hoc village	Young farmer, head of the forest protection group	Forest changes and forest protection
12	M	? >60	At his home, Hoc village	Retired farmer, former leader of the village (until 2004) and chairman of commune (1986–2003)	History of land uses and policies
13	M	? 25–35	In the forest, Hoc village	Young farmer, vice-head of forest protection group	Transect walk, forest status, quality and changes
14	F	? 25–35	At her home and in the uplands, Hoc village	Housewife	Changes in forest uses and forest products availability, forest policies, livelihoods. Transect walk about forest products availability and forestland allocation
15	M	? >60	At his home, Hoc village	Retired farmer	Black Thai traditional ecological knowledge and forest classification
16	M	? 25–35	At his home, Hoc village	Young farmer, head of village and our host	Livelihoods, agricultural activities, reforestation projects
Interviews and group discussions on environmental perceptions					
17	M	49	At his home, Hoc village	Rich farmer, vice-head of village	Same as key informant 10
18	M	58	At his home, Hoc village	Poor farmer	
19	M	28	At his home, Hoc village	Young and poor farmer	Same as key informant 11
20	M	58	At his home, Hoc village	Middle-class farmer	
21	M, F	20–>60	At the home of the village head, Hoc village	Group discussion & map: 17 people: 6 women, 3 old men, 3 middle-aged men, 5 young men, mostly farmers, spread among richer and poorer	

Table 9 (continued)

Interview n°	Gender	Age	Context	Status	Topics
Pa Dong					
Key informants					
22	M	? 30–40	At a table outside of the shop, Pa Dong village	Middle-class farmer	Livelihoods, agricultural changes, land policies
23	M	? >60	At a table outside of his shop, Pa Dong village	Retired teacher and former head of village (1975–1980)	General and land use history of the village, land zoning policies
24	M	? 30–40	At his home, Pa Dong village	Rich farmer, leader of the forest protection group	Forest changes, forest protection, illegal activities
25	M	? >50	At his home, Pa Dong village	Rich farmer, our host, vice-chairman of commune PC, former head of the village (1980–1985)	Several interviews, land use history, livelihoods, policies, reforestation programs
26	M	? >50	At his home and at the home of the vice-chairman of commune PC, Pa Dong village	Farmer, head of village	Several interviews, agriculture, livelihoods, policies, reforestation programs
27	M	? 25–35	In the forest and uplands, Pa Dong village	Young farmer, well-educated (forestry college), member of the forest protection group	Transect walks, forest changes, reforestation programs, land allocation policies
28	M	? >60	At his home, Pa Dong village	Retired farmer, former leader of the village (1985–1994 & 1995–1999)	Land use and regulations history
Interviews and group discussions on environmental perceptions					
29	M	36	At his home, Pa Dong village	Middle-aged rich farmer, chair of CP of village	
30	M	45	At his home, Pa Dong village	Middle aged farmer, vice-leader of village	
31	M	52	At his home, Pa Dong village	Old farmer	
32	M	? >50	At his home, Pa Dong village	Old farmer	
33	M, F	20–>60	At the home of the vice-chairman of commune PC, Hoc village	Group discussion & map: 17 people: 5 women, 3 old men 6 middle-aged men, 3 young men, mostly farmers, spread among richer and poorer	
Xuan Lac commune and regional perspective					
34	M	? >50	In his office, at Bac Kan DARD, Bac Kan town	Vice-director of sub-department of forestry from Bac Kan province DARD	Patterns of forest changes in the region and forest policies
35	M	? 30–40	In his office, at Bac Kan DARD, Bac Kan town	Officer from technical division of forestry department from Bac Kan province DARD	Patterns of forest changes in the region and forest policies
36	M	? 30–40	Dong Lac ranger station, on the road in Dong Lac commune, Nam Sach district	Head of rangers at Dong Lac station (covering Xuan Lac commune).	Forest changes, illegal activities, forest policies
37	M	? 30–40	Dong Lac ranger station, on the road in Dong Lac commune, Nam Sach district	Ranger on Xuan Lac commune, from Dong Lac station	Forest changes, illegal activities, forest policies
38	M	? 40–50	At Xuan Lac PC building, O' village	Vice-chairman of PC	Many interviews about general features of the commune, paddy rice cultivation, forest changes, policies and livelihoods
39	M	? >60	At Xuan Lac PC building, O' village	Former chairman of PC (1980–1990)	History of land use and policies, reforestation programs
40	M	? 50–60	At Xuan Lac PC building, O' village	Chairman of PC	Forest and land use policies, land allocation, reforestation programs
41	M	? 40–50	At the home of the vice-chairman of Xuan Lac PC, Khang village	Commune officer for land management	Two interviews about forestland classification and policies
Khang					
Key informants					
42	M	? 40–50	At the home of the vice-chairman of PC and in the forests and uplands, Khang village	Head of the village, and member of the Nam Xuan Lac protection group	General features of the village. Two transect walks about various topics related to forestry and other activities.
43	M	42	At his home and in the fields, Khang village	Successful farmer and innovator, leader of the village 1998–2004	Agriculture, upland crops and emerging agricultural and forestry activities
44	M	? 40–50	At his home and in the paddyfields, Khang village	Farmer, our host, vice-chairman of PC	Many interviews about general features of the village, population, paddy rice cultivation, forest policies

Table 9 (continued)

Interview n°	Gender	Age	Context	Status	Topics
45	M	55	At his home, Khang village	Old farmer	Long term trends of population, land use and agriculture, and traditional Tay ecological knowledge
46	M	>60	At the home of the vice-chairman of PC, Khang village	Old farmer	Traditional Tay ecological knowledge and forest classification system
Interviews and group discussions on environmental perceptions					
47	M	42	At his home, Khang village	Successful farmer and innovator	
48	M	34	At his home, Khang village	Middle-class farmer and policeman	
49	M	>60	At his home, Khang village	Poor and old farmer	Same as key informant 46
50	M	49	At his home, Khang village	Middle-class farmer	
51	M, F	20–>60	At the cultural house of Khang village	Group discussion & map: 19 people: 9 women, 3 old men, 3 middle-aged men, 4 young men, mostly farmers, spread among richer and poorer	
Na Da					
Key informants					
52	M	>50	At his home, and in the uplands and forests, Na Da village and Nam Xuan Lac preservation area	Head of the village and host	Many interviews about general features of the village, land use, forest changes, and many other topics. + three transect walks about various topics, including forest changes, agriculture, forestry and illegal activities, traditional ecological knowledge
53	M	44	At his home, Na Da village	Rich farmer, policeman, former village head, and member of the Nam Xuan Lac protection group	Several interviews about forest changes and protection, and reforestation
54	M	32	At his home, Na Da village	Lucky farmer and "new rich"	Forestry, logging and other upland activities
55	M	55	At the home of the head of the village	Middle class farmer	Agricultural changes and abandonment of shifting cultivation
Interviews and group discussions on environmental perceptions					
56	M	55	At his home, Na Da village	Middle-class farmer, former head of the village	
57	M	44	At his home, Na Da village	Poor farmer	
58	F	21	At her home, Na Da village	Young girl and daughter of a rich farmer	
59	M	30	At his home, Na Da village	Young and very poor farmer	
60	M	40	At his home, Na Da village	Middle-class farmer	
61	M, F	20–>60	At the cultural house of Na Da village	Group discussion & map: 18 people: 4 women, 2 old men, 4 middle-aged man, 8 yound men, mostly farmers, spread among richer and poorer	

Notes on the attendance: interviews realized at home were always conducted in presence only of the interviewers and sometimes of the interviewee's family (wife, children, or parents). Interviews and group activities conducted in People's Committee buildings, cultural houses or other public places were often attended by at least one member of the commune's PC (which was usually part of the group discussion). Three of the people interviewed about environmental cognitions were also key informants, as mentioned in column 6. In that case, the two sets of interviews were clearly separated and conducted at another moment.

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