Working Paper

Landuse/cover change in Ho Ho Sub-watershed, north-central Viet Nam

Mai Phuong Nguyen, Bac Viet Dam, Duc Anh Ngo and Rachmat Mulia

World Agroforestry Centre

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Abstract

Landuse analysis and local knowledge can explain the intensity and drivers of landuse changes in a rural landscape. In the Huong Khe watershed north-central Viet Nam, during recent decades (1990-2014), this analysis identified a massive transformation of natural forests into farm-based plantations of rubber and acacia. Population growth also forced large areas of forest land to be allocated to local people for their livelihoods, and induced an increase in cultivated lands, such as shifting cultivation in uplands, and settlements. The Ho Ho sub-watershed is part of the Huong Khe watershed and a similar trend was observed there with the remarkable expansion of acacia forest plantations to supply the pulp industry. The conversion from logged over forest into acacia plantation occurred both in the upstream and downstream communes of the sub-watershed. Claims by local people for land to feed the growing population, over logging and the forest plantation expansion program were responsible for forest degradation and conversion. The local people foresaw that expansion of the acacia forest plantations would continue in the future driven by high economic as well as presumably environmental benefits such as landslide prevention and micro-climate regulation, along with a steady increase in the total population.

Keywords: Landuse change, local knowledge, spatial analysis, sub-watershed

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I. Introduction

Study of the vulnerability and local knowledge on the role of trees in livelihoods and the environment requires analysis of the drivers of landuse change and distribution (Hoang et al. 2014, Nguyen et al. 2013, Pfund et al. 2011). The landuse mosaic in the landscape determines the degree of exposure, sensitivity and adaptive capacity of the landscape and its inhabitants, and reflects the local view and value of the role of tree planting in livelihoods and environmental service functions. Analysis of the drivers of landuse change will explain any gap found between local knowledge on landuse functions and action that leads to actual landuse distribution in the landscape. In this paper, we present landuse/cover distribution and change in the Huong Khe watershed during the last few decades, using 1990, 2000 and 2014 as a representative sample. Huong Khe is a watershed in north-central Viet Nam and includes the Ho Ho sub-watershed where the studies of vulnerability (Mulia et al., 2015) and local knowledge on the role of trees (Dam et al., 2015) were carried out.

1.1 Study sites

Huong Khe is a mountainous district in Ha Tinh province, north-central Viet Nam. It stretches from 17°58’ to 18°23’ N and from 105°27’ to 105°56’ E. The district experiences the tropical monsoon in two seasons: i) the hot season from April to August with dry and hot weather and in particular, the district is severely affected by southwest winds in June and July; ii) the cold season starts in November and ends in March with the northeast monsoon and rain. Based on the 1982-2011 weather data records for Huong Khe district obtained from the Institute of Meteorology, Hydrology and Climate change (IMHEN), the average temperature in the area was 25 °C with an average maximum and minimum of 28.7 °C and 21.2 °C, respectively. The average annual rainfall was about 2500 mm. The rainy season takes place between August and September, with the average total rainfall being 1425 mm or equivalent to 60 percent of the annual rainfall. January and February are the driest months, with an average total monthly rainfall of only 96.6 mm. The topography of the sub-watershed is dominated by rivers and streams.

The Ho Ho sub-watershed (Fig. 1) is part of the Huong Khe watershed which stretches across Huong Khe district in Ha Tinh province and across Tuyen Hoa district in Quang Binh province. The sub-watershed covers an area of 26073 ha, and is mostly situated within the Huong Khe district with its final tributary in Tuyen Hoa district. Tuyen Hoa is a mountainous district in north-central Viet Nam, Quang Binh province. It consists of 115000 ha, accounting for 14.27 percent of the total area in the province. The Ho Ho sub-watershed covers nearly half of the Huong Hoa (downstream) commune in Tuyen Hoa district. The topography of the Ho Ho sub-watershed is mainly intersected with rivers and streams and has hilly areas, with cultivated land in the northwest part. The main river is the Ngan Sau River that flows across the sub-watershed with a length of more than 10 km to the Ho Ho dam as the final tributary. The dam is used to generate hydroelectricity and to supply irrigation to the downstream commune.

The total population of the sub-watershed in 2014 was about 10000 people (equivalent to 3500 households). The average population density was 41.5 people km^{-2} in the upstream (Huong Lam and Huong Lien) commune and 30.2 people km^{-2} in the downstream (Huong Hoa) commune. Of the total population, 62.5 percent live in the upstream commune and the remainder are in the downstream commune. The people in the sub-watershed depend on agriculture as their main source of livelihood. The dominant crops are peanuts, paddy rice, maize, sweet potatoes, green beans and cassava. Livestock include pigs, cows, buffaloes and chickens. Farmers usually have fruit trees in home gardens and timber trees such as *Acacia spp., Aquilaria crassna* and *Dalbegia tonkinensis* in small woodlots. Some farmers also earn income from non-farm jobs as construction labourers and public and private employees for example (Dam et al. 2015).

Figure 1. Location of Huong Khe watershed in Ha Tinh province and Ho Ho sub-watershed in Quang Binh province, north-central Viet Nam

1.2 Materials and methods

To produce the landcover map, we obtained remote sensing data (Landsat) for 1990, 2000 and 2010 and used the landuse maps from the Ministry of Natural Resources and Environment as a reference. Secondary data from the study site and also ground truthing were used to verify the landcover maps (Fig. 2).

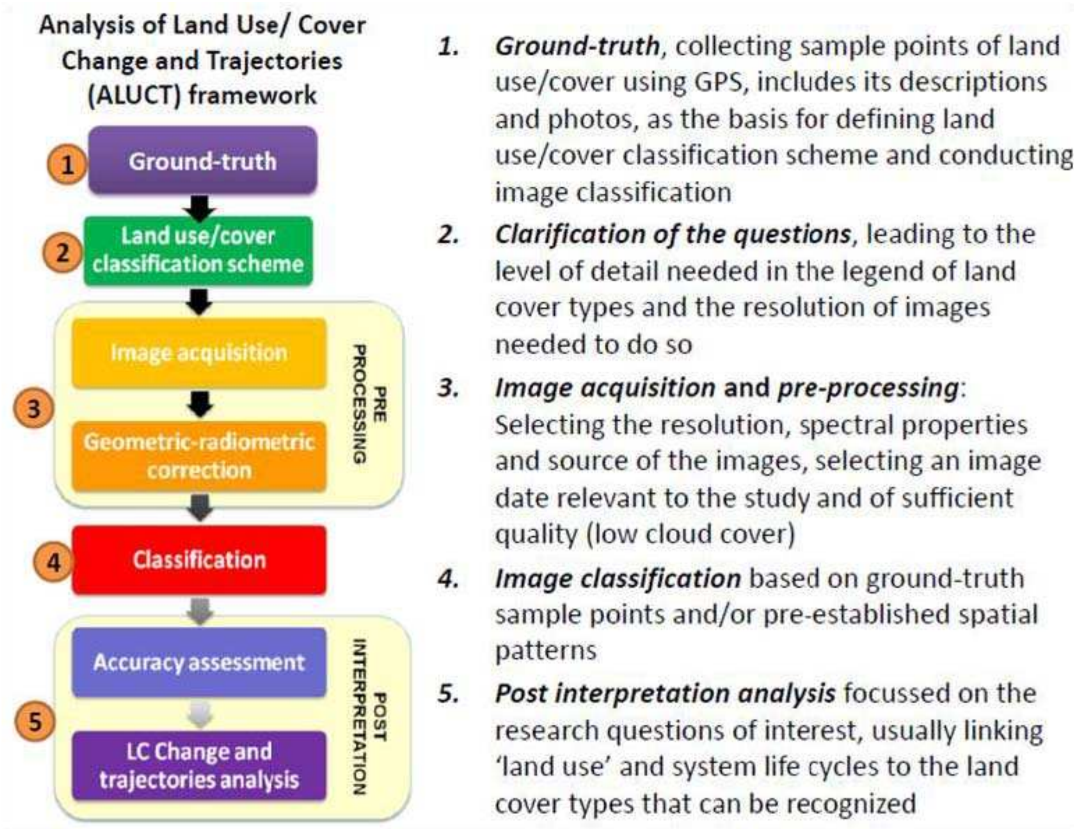


Figure 2. Framework of landuse/cover change analysis based on Dewi and Ekadinata (2013)

1.2.1 Image pre-processing

Before the landcover identification process, the clarity of Landsat images was improved by applying atmospheric correction and colour enhancement (Fig. 3). The 2014 image had some missing information due to a problem in the satellite sensor; therefore, another Landsat reference image was used to provide the missing data.

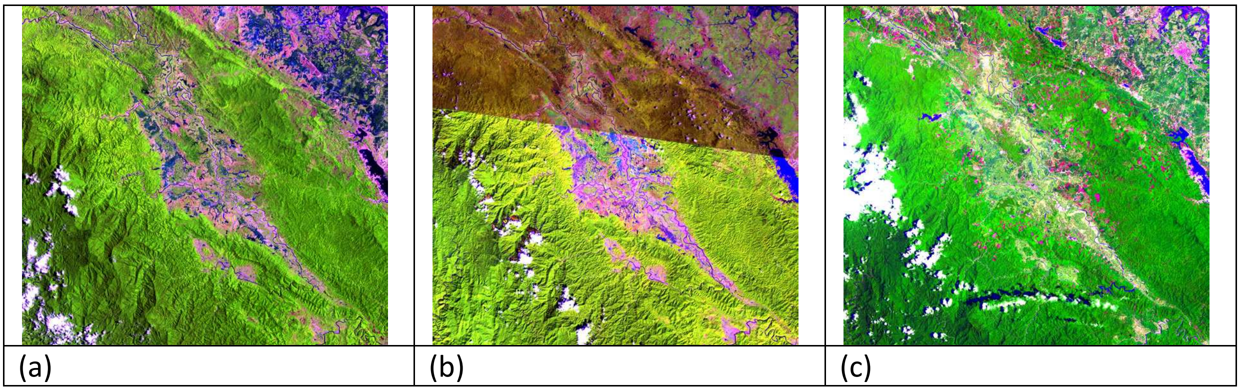


Figure 3. Landsat image for Huong Khe watershed, north-central Viet Nam in (a) 1990, (b) 2000 and (c) 2014

1.2.2 Image classification

In order to produce landcover maps from the satellite data, we applied an object-based classification technique and one of the important steps in object-based classification is the image segmentation process, for which we used multi-resolution segmentation in the Ecognition software *(http://www.ecognition.com/category/related-tags/object-based-classification)* (Fig. 3a). This process requires scrutiny in order to achieve an accurate classification result. In this study, we used different parameters to examine the effectiveness of the segmentation process. The step following segmentation is image classification, which assigns attribute values to the polygons. In order to classify the segmented images, we need to calculate image statistical parameters for each polygon including the mean and standard deviation of each image band. The image classification follows the landuse/cover system hierarchy developed by Dewi and Ekadinata (2013) (Fig. 4) with landuse types not existing in the study site such as mangroves, cacao, coconut, oil palm and dry land being removed from the classification process.

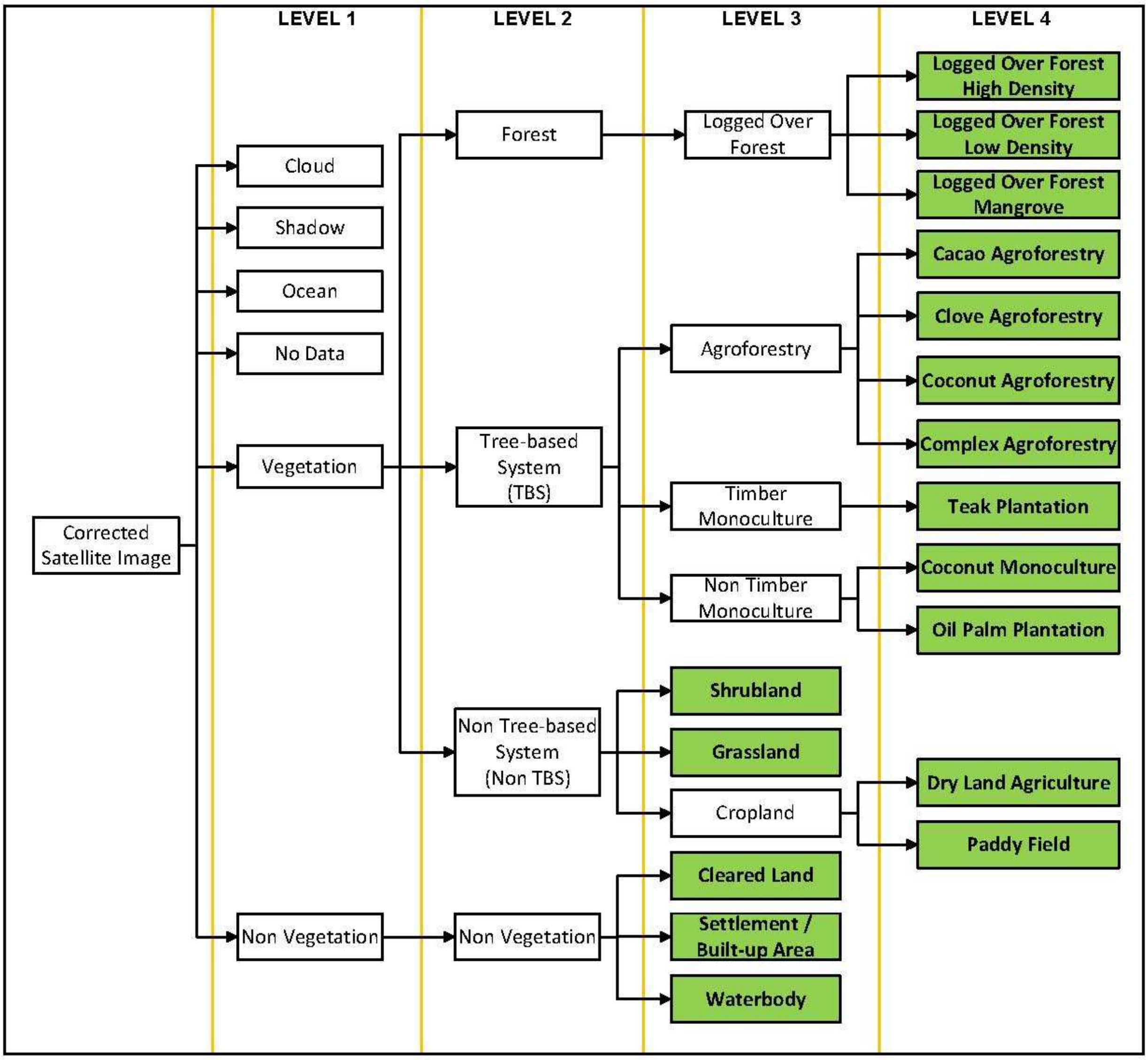
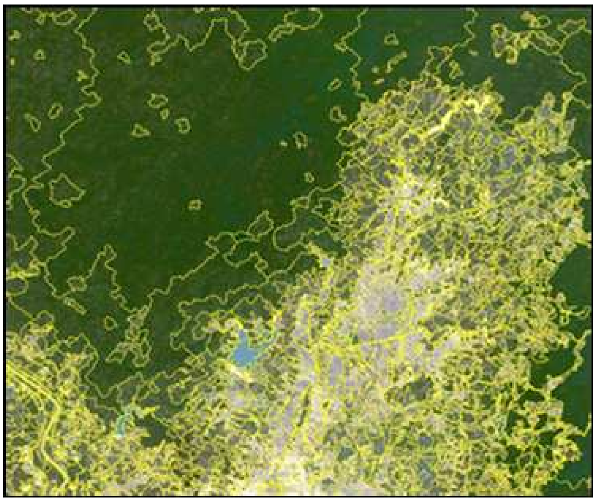
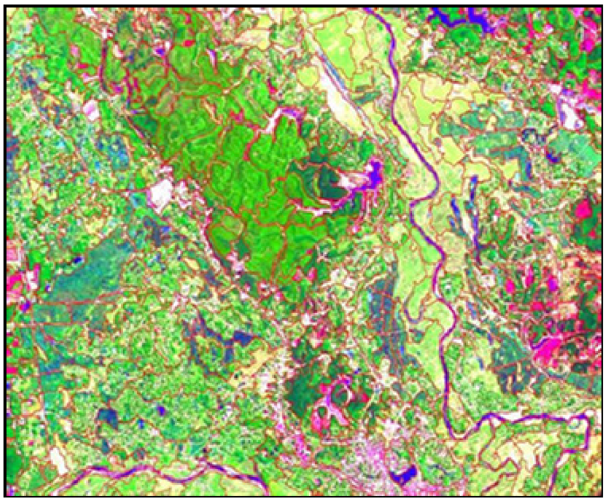


Figure 4. Landuse/cover system hierarchy for image classification used to classify landcover types in Huong Khe watershed, north-central Viet Nam based on Dewi and Ekadinata (2013)

We used WEKA (Waikato Environment for Knowledge Analysis), open-source software *(http://www.cs.waikato.ac.nz/ml/weka/)* for image classification. It contains tools for data pre-processing, classification, regression, clustering, association rules and visualization. Initially, after calculating statistical parameters for each polygon (the software can process an unlimited number of image channels), the sampling process uses image interpretation based on the segmentation results. The number of polygons for interpretation is about 5-10 percent of the total number of polygons. In this step, the accuracy of results will strongly depend on the accuracy of the sampling process. Subsequently, the attribute table with a 'sample class' column is imported into WEKA for classification. In this study, we chose 'random forest' as the classification algorithm type. All classifications were stored into a new column named 'predict class' in the attribute table. The next step was to export the image segments into a vector format (shape file) and overlay with the landuse map from MONRE using the Arc GIS software (Fig. 5). We needed to check the initial results and to identify the points in the produced maps to collect and compare with the field data.



(a)



(b)

Figure 5. Landsat image classification process that includes (a) Image segmentation and (b) Overlaid post-segmentation image on referenced landuse map

1.2.3 Map editing

To produce final landcover maps, the classification results (polygon boundary and attributes) should be compared with the field data and ground truthing. The field data were organized into an MS Access database that included GPS coordinates, date, time, location, landuse type and images. Table 1 shows the final landcover classification used to produce the landcover maps.

Table 1. Final landcover classification to produce the landcover map of Huong Khe watershed, north-central Viet Nam

Id	Class	Acronym	Description
1	Undisturbed forest	UndFor	Primary natural forest
2	Logged over forest	LogFor	Secondary natural forest
8	Others agroforest	OtherAF	Trees on bare land, grass or cropland
10	Pulp plantation	Pulp	Planted forest for pulp production (Acacia)
11	Other forest plantations	OtherFP	Other planted forest types
12	Rubber monoculture	RubMono	Rubber plantation
15	Shrub	Shrub	Bare land with grass and shrubs
16	Annual crop land	Crop	Annual crops such as rice, maize, cassava, peanut
17	Grass	Grass	Grazing land
18	Shifting cultivation	StCult	Upland areas of maize, rice or cassava
19	Others cleared lands	OtherCL	Other bare lands
20	Settlement	Set	Residential and built-up areas
21	Waterbody	Water	Rivers, streams, lakes
22	Cloud and shadow	CSh	Areas under cloud and shadow on LANDSAT images

1.2.4 Accuracy assessment

Two methods are available to assess the accuracy of image classification namely ‘field’ that employs the ground data collection and ‘room’ with the reference dataset. In this study, we applied the second method using a K (Kappa) coefficient (*https://en.wikipedia.org/wiki/Cohen’s_kappa*). K measures the percentage of data values in the main diagonal of the table and then adjusts these values based on the amount of conformity that could be expected due to chance alone. Two raters are asked to classify objects into category 1 and 2 producing a 2x2 table with a set of probability values. K values are less than or equal to 1. A unit value implies perfect conformity. An interpretation for a K values less than 1 can be: <0.2 = poor conformity, 0.2-<0.4 = fair conformity, 0.4-<0.6 = moderate conformity, 0.6-<0.8 = good conformity, and 0.8-<1 = very good conformity. When comparing landcover maps in 2000 and 2010 with forest maps obtained from the Forest Inventory and Planning Institute (FIPI) as a reference, the calculated K coefficient equals 0.49 and 0.51 for the 2000 and 2010 maps, respectively, which indicates that there is a moderate level of conformity between the landcover maps produced in this study and the forest maps.

1.2.5 Landuse/cover change analysis

The changes in landuse/cover were identified using the post classification technique (Dewi and Ekadinata 2013). The land cover maps in 1990, 2000 and 2014 were employed to produce the landuse change matrices for the periods 1990-2000, 2000-2014 and 1990-2014, for the Huong Khe watershed and the Ho Ho sub-watershed.

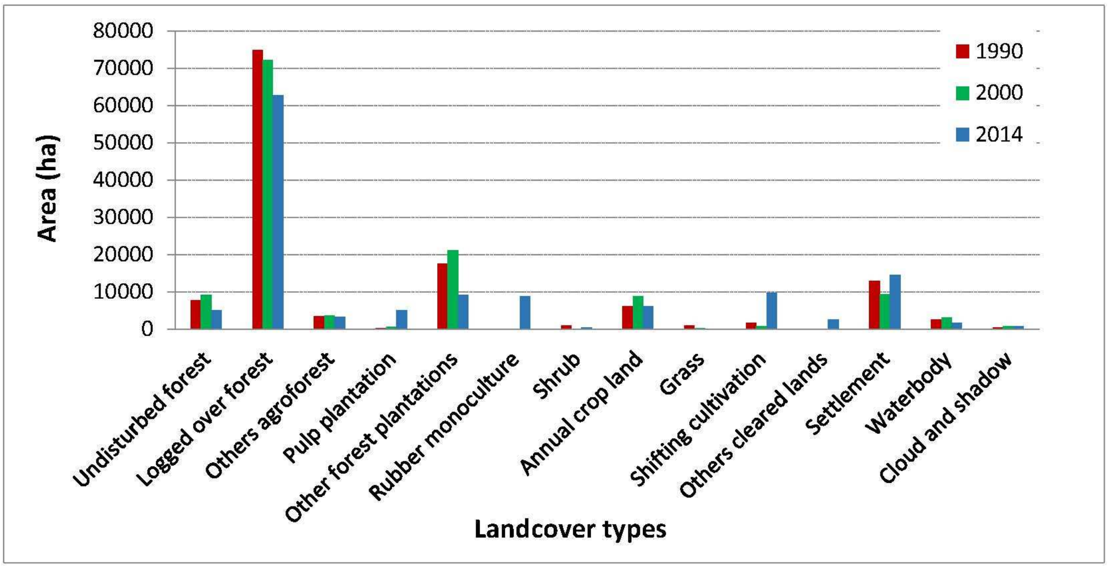
1.2.6 Drivers of landuse change based on local knowledge

In the segregated focus group discussions (FGDs) with men and women, we asked farmers to recall the changes in landuses from 2000 to 2014 and the related drivers. They identified five dominant landuses, namely natural forest, plantation forest, cropland, residential and paddy rice land. For a rapid appraisal of drivers of landuse change, we applied the DriLUC framework (van Noordwijk 2013) with a female-only group and a male-only group in each of the upstream and downstream communes of the sub-watershed. Each group consisted of nine people, involving 18 female and 18 male respondents per commune. The participants were representative of farmers from different age classes and land ownership status.

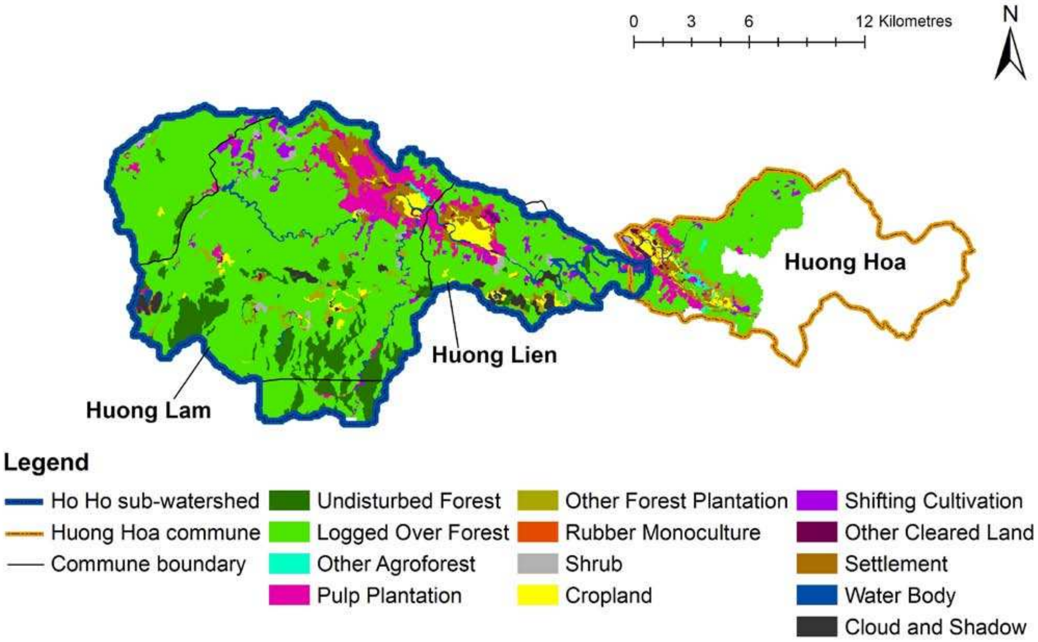
2. Results

2.1 Landuse change in Huong Khe watershed

Figure 6a shows the total area of each landcover type in the Huong Khe watershed in the three observed years. The total area of landcover change between 1990 and 2000 in this watershed was 9000 ha, with a significant increase up to 30000 ha in 2000-2014. The increase in rubber monoculture (8864 ha equivalent to a 7 percent net increase relative to the total watershed area), shifting cultivation with cassava (7597 ha, 6 percent), settlement (5213 ha, 4 percent), pulp plantation (4460 ha, 3 percent) and other cleared lands (2588 ha, 2 percent) dominated the landcover change in 2000-2014. Specifically, no cultivated land with the rubber monoculture landuse type was found in 2000. The landcover types with declining area in 2000-2014 included other forest plantations (11982 ha, 9 percent less in 2014 relative to total watershed area), logged over forest (9655 ha, 8 percent), undisturbed forest (4001 ha, 3 percent), annual crop lands (2638 ha, 2 percent), and water body (1631 ha, 1 percent).



(a)



(b)

Figure 6. a) Landcover distribution and area in Huong Khe watershed in 1990, 2000, and 2014 and b) Landcover map of Ho Ho sub-watershed in 2014

2. 2 Landcover changes in Ho Ho sub-watershed

Figure 6b shows the landcover map of the Ho Ho sub-watershed in 2014 and Table 2 shows the landcover distribution and area in the sub-watershed in 1990, 2000 and 2014. The area of pulp plantation, shifting cultivation with cassava, annual crop lands with rice, maize, peanut, cassava, and other cleared lands increased from 2000 to 2014; while undisturbed forest and other forest plantation decreased. The area of undisturbed forest decreased by 1518 ha whereas other forest plantations decreased by 1267 ha. Specifically for the logged over forest that dominated the landscape of the sub-watershed, there was a substantial decrease of 1326 ha in 1990-2000, but then an increase of 609 ha in 2000-2014.

Table 2. Landcover distribution and areas in Ho Ho sub-watershed in 1990, 2000 and 2014

Landcover types	Land area					
	1990		2000		2014	
	ha	%	ha	%	ha	%
Undisturbed forest	3724	14.3	3891	14.9	2373	9.1
Logged over forest	19006	73.0	17680	67.9	18289	70.2
Other agroforest	24	0.1	24	0.1	24	0.1
Pulp plantation	345	1.3	459	1.8	1512	5.8
Other forest plantations	620	2.4	1604	6.2	337	1.3
Shrub	313	1.2	0	0	251	1.0
Annual crop land	380	1.5	509	2.0	647	2.5

Landcover types	Land area					
	1990		2000		2014	
	ha	%	ha	%	ha	%
Grass	68	0.3	0	0	0	0
Shifting cultivation	124	0.5	167	0.6	584	2.2
Other cleared land	0	0	2	0.0	91	0.3
Settlement	916	3.5	952	3.7	980	3.8
Water body	519	2.0	646	2.5	519	2.0
Cloud and Shadow	0	0	105	0.4	432	1.7

2.2.1 Landcover transition in Ho Ho sub-watershed between 1990 and 2000

The main landcover conversion between 1990 and 2000 includes transition of 1314 ha of logged over forest into undisturbed forest (Table 3). In the same time, however, 1035 ha of existing undisturbed forest was converted into logged over forest, which was equivalent to 28 percent of the undisturbed forest area in 1990. In that decade, a large area of logged over forest was converted into other forest plantations (1015 ha) and smaller amounts into pulp plantation (129 ha), annual crop lands (115 ha), and shifting cultivation (65 ha).

Table 3. Landcover transition in Ho Ho sub-watershed between 1990 and 2000

1990\2000	UndFor	LogFor	OtherAF	Pulp	OtherFP	Crop	StCult	OtherCL	Set	Water	CSh
UndFor	2556	1035			11	24	9		7	48	33
LogFor	1314	16170		129	1015	115	65	0		125	71
OtherAF			24								
Pulp		43		254	7	12	11		18		
OtherFP		145		46	417				13		
Shrub		227			86						
Crop		6			11	328		0	36		
Grass					31	4		2	31		
StCult	6	9		30	25		53				
Set		9				28	24		846	9	
Water	15	37					5	0		463	

2.2.2 Landcover transition in Ho Ho sub-watershed between 2000 and 2014

A massive conversion of undisturbed forest (1600 ha) into logged over forest occurred in 2000-2014 (Table 4). In the same period, 444 ha of logged over forest was converted into pulp plantation, 302 ha into other forest plantations and 529 ha into shifting cultivation with cassava. A substantial conversion also occurred in other forest plantations with 978 ha into logged over forests and 590 ha into pulp plantation.

Table 4. Landcover transition in Ho Ho sub-watershed between 2000 and 2014

2000\2014	UndFor	LogFor	OtherAF	Pulp	OtherFP	Shrub	Crop	StCult	OtherCL	Set	Water	CSh
UndFor	**2164**	1600		0	35	24	19		5		3	40
LogFor	189	**15379**		444	302	149	150	529	6	128	26	378
OtherAF			**24**									
Pulp		61		**386**		12						
OtherFP		978	0	590	0	36	0					
Crop		57		12			**441**					
StCult		70				30	2	0	20	44		
OtherCL							0		2			
Set		20		79			36	21	13	**783**		
Water		56						32	44	25	**489**	
CSh	20	68						2				**14**

2.3 Landcover distribution in upstream commune of Ho Ho sub-watershed

In the upstream (Huong Lam and Huong Lien) commune, the area of pulp plantation increased substantially from 334 ha in 1990 to 1440 ha in 2014 (Table 5). Shifting cultivation with cassava and annual crop lands also expanded by 416 ha and 243 ha, respectively, during that period. Undisturbed forest cover decreased by 890 ha, logged over forest by 1042 ha, and other forest plantation types by 1244 ha.

Table 5. Landcover distribution and areas in the upstream commune of Ho Ho sub-watershed in 1990, 2000 and 2014

Landcover types	Land area					
	1990 ha	%	2000 ha	%	2014 ha	%
Undisturbed forest	2698	12.6	2551	11.9	1808	8.4
Logged over forest	15532	72.4	14558	67.9	14490	67.6
Other agroforest	24	0.1	24	0.1	24	0.1
Pulp plantation	334	1.6	458	2.1	1440	6.7
Other forest plantation	580	2.7	1554	7.2	309	1.4
Shrub	309	1.4	0	0	227	1.1
Annual crop lands	380	1.8	505	2.4	623	2.9
Grass	66	0.3	0	0	0	0
Shifting cultivation	117	0.5	138	0.6	533	2.5
Other cleared land	0	0	0	0	80	0.4
Settlement	916	4.3	952	4.4	975	4.5
Water body	490	2.3	611	2.8	507	2.4
Cloud and shadow	0	0	94	0.4	428	2.0

2.3.1 Landcover transition in upstream commune from 1990 to 2000

Massive forest degradation occurred in the upstream commune of the Ho Ho sub-watershed with 809 ha of undisturbed forest converted into logged over forest (Table 6). In the same period, due to natural regeneration, 788 ha of logged over forest was converted into undisturbed forest while another 978 ha were cleared into other forest plantations.

Table 6. Landcover transition in upstream commune of Ho Ho sub-watershed from 1990 to 2000

1990\2000	UndFor	LogFor	OtherAF	Pulp	OtherFP	Crop	StCult	Set	Water	CSh
UndFor	1763	809			11	22	6	7	46	33
LogFor	788	13314		129	978	113	51		97	61
OtherAF			24							
Pulp		43		254	7	12		18		
OtherFP		116		45	406			13		
Shrub		227			83					
Crop		6			11	328		36		
Grass					31	4		31		
StCult		9		30	25		53			
Set		9				28	24	846	9	
Water		26					5		458	

2.3.2 Landcover transition in upstream commune from 2000 to 2014

In this decade, 338 ha of logged over forest and 575 ha of other forest plantations were converted to pulp plantation with acacia (Table 7). A large conversion of logged over forest into cultivated land also occurred including 281 ha into other forest plantations, 139 ha into croplands, 128 ha into shifting cultivations and 128 ha into settlement. We also observed 943 ha in transition from other forest plantations to logged over forest. This explains why the total area of logged over forest remained stable during 2000-2014.

Table 7. Landcover transition in upstream commune of Ho Ho sub-watershed from 2000 to 2014

2000\2014	UndFor	LogFor	OtherAF	Pulp	OtherFP	Shrub	Crop	StCult	OtherCL	Set	Water	CSh
UndFor	1666	805			28		12					40
LogFor	121	12454		388	281	149	139	490	6	128	26	375
OtherAF			24									
Pulp		61		386		12						
OtherFP		943		575	0	36						
Crop		57		12			436					
StCult		51				30		0	16	40		
Set		20		79			36	21	13	783		
Water		40						23	44	24	480	
CSh	20	60										14

2.3.3 Drivers of landuse change in upstream according to local knowledge

Local people claimed there was a decrease in the annual crop area over the period 2000-2014. The male group identified landslides as the sole cause, while the female group highlighted flash flooding as one of the main drivers that leads to landslides, riverbank erosion and destruction to agricultural plots (Table 8). Another driver was land conversion into paddy or settlement. In general, however, the area of paddy was considered to also have decreased due to landslides and the lack of irrigation as a consequence of drought. Consequently, locals converted paddy areas into other landuse types. Due to the growing population, forest lands were allocated for livelihood, and with illegal logging, reduced the area of natural forests in the upstream commune. The afforestation program induced massive conversion of natural forests (mostly logged over forest) into acacia plantation. Related to the change in the area of paddy and annual crops, female groups could identify more specific drivers than the males, most likely because women were involved mainly in agriculture while men focused more on the forestry areas.

Table 8. Drivers of historical landuse changes (2000-2014) based on local knowledge in the upstream commune of Ho Ho sub-watershed

Landuse change 2000-2014	Drivers according to males	Drivers according to females
Less area of annual crops	Landslides	Flash flooding causing landslides and riverbank erosion, and destruction of annual crop plots Conversion into paddy or settlement
Less area of paddy	Landslides Lack of irrigation	Flash flooding causing landslides and riverbank erosion, and destruction of paddy plots Drought
More area of settlement	Growing population	Growing population
Natural (i.e. undisturbed or logged over) forests to acacia	Planted forest expansion program (i.e. land allocation by the government to local people and support for open acacia plantation)	Planted forest expansion program (i.e. land allocation by the government to local people and support for open acacia plantation)
Less area of natural forests	Conversion into plantation Illegal logging	Conversion into plantation Illegal logging

2.4 Landcover distribution in downstream commune of Ho Ho sub-watershed

In 2000-2014, pulp plantation with acacia increased by 360 ha (equivalent to 8.6 percent of the total sub-watershed area) in the downstream commune of the sub-watershed (Table 9). The population also grew rapidly and required 182 ha of land for conversion into settlements. The area of logged over forest as the dominant landcover type expanded by 154 ha due to transition from other landcover/use types. In the downstream commune, no undisturbed forests remained in 2014.

Table 9. Landcover distribution and areas in the downstream commune of Ho Ho sub-watershed in 1990, 2000 and 2014

Landcover types	Land area					
	1990 ha	**%**	**2000 ha**	**%**	**2014 ha**	**%**
Undisturbed Forest	18	0.4	7	0.2	0	0
Logged Over Forest	3010	71.5	2743	65.2	2897	68.8
Other Agroforest	64	1.5	106	2.5	87	2.1
Pulp Plantation	0	0	0	0	360	8.6
Other Forest Plantation	243	5.8	717	17.0	126	3.0
Shrub	174	4.1	29	0.7	11	0.3
Cropland	399	9.5	383	9.1	218	5.2
Grass	49	1.2	0	0	0	0
Shifting Cultivation	4	0.1	0	0	111	2.6
Other Cleared Land	0	0	67	1.6	79	1.9
Settlement	132	3.1	78	1.9	260	6.2
Water body	116	2.8	80	1.9	60	1.4

2.4.1 Landcover transition in downstream commune from 1990 to 2000

The most evident landuse conversions in the downstream commune between 1990 and 2000 were 322 ha of logged over forest and 128 ha of shrub into other forest plantation (Table 10). In this decade, the remaining 18 ha of undisturbed forest were degraded into logged over forest.

Table 10. Landcover transition in downstream commune of Ho Ho sub-watershed from 1990 to 2000

1990/2000	**UndFor**	**LogFor**	**OtherAF**	**OtherFP**	**Shrub**	**Crop**	**OtherCL**	**Set**	**Water**
UndFor	**0**	18							
LogFor	0	**2673**	1	322	1	3	4		4
OtherAF		1	**59**	3		0	0		0
OtherFP		10	3	**223**	1	3	0		2
Shrub		31	2	128	**12**	1			
Crop		9	23	31	13	**250**	45	20	8
Grass		0	12	6	1	26	3		
StCult			2	1		1			
Set		0	1	1		69	4	**59**	
Water	7	0	1	1		30	12		**65**

2.4.2 Landcover transition in downstream commune from 2000 to 2014

In 2000-2014, land conversion was less than in 1990-2000 (Table 11). The largest conversions consisted of 495 ha of other forest plantation into logged over forest (203 ha) and pulp plantation (292 ha). Due to the growing population, 159 ha of cropland were converted into settlement.

Table 11. Landcover transition in downstream commune of Ho Ho sub-watershed from 2000 to 2014

2000/2014	**UndFor**	**LogFor**	**OtherAF**	**Pulp**	**OtherFP**	**Shrub**	**Crop**	**StCult**	**OtherCL**	**Set**	**Water**
UndFor		0					7				
LogFor	0	**2677**		56	0		2	8	0		
OtherAF			**41**	9	4		1	33		18	
OtherFP		203	40	292	**121**		2	52	0	7	
Shrub		12			**1**	**0**	0	7	0	9	
Crop		4	5	1	0	11	**170**	2	31	159	
OtherCL		1		0			11	0	**45**	10	
Set			2				24		0	**53**	
Water		0		2			1	9	2	5	**60**

2.4.3 Drivers of landuse change in downstream according to local knowledge

In the downstream commune, landslides and conversion into paddy fields resulted in a decrease in the area of annual crops during 2000-2014 (Table 12). The female group added low economic value as another factor inducing conversion. The male and female groups had contrasting views regarding the change in paddy area. The male group claimed landslides from a hydropower plant reduced the area of paddy field in the downstream commune. The female group didn't mention the landslide problem, but instead highlighted the improved irrigation system in some villages in the commune, which had triggered conversion of maize into paddy fields. Locals in the upstream and downstream communes had similar views about the declining area of natural forest. The growing population requiring more land to be allocated to sustain livelihoods, subsequent conversion to acacia plantations, and over logging were identified as the main causes of forest conversion.

Table 12. Drivers of historical landuse changes (2000-2014) based on local knowledge in the downstream commune of Ho Ho sub-watershed

Landuse change 2000-2014	Drivers according to male	Drivers according to female
Less area of annual crops	Landslides from the hydropower plant Change to paddy because of better irrigation system	Landslides Change to paddy Low economic value
More areas of paddy according to females and less area of paddy according to males	Landslides from the hydropower plant	Better irrigation system Conversion from maize into paddy
More areas of settlement	New public lands managed by communal office (public lands are also considered as 'settlement')	Growing population Better infrastructure Need more stables for animals
Natural (undisturbed or logged over) forests to acacia	Growing population needs more land allocated to sustain livelihoods	Growing population needs more lands to sustain livelihoods
Less area of natural forests	-	Expansion of plantation forest (acacia) Over logging

3. Discussion

Local people made a differentiation between paddy and annual crops (such as maize, cassava, peanuts and beans), while spatial analysis classified both as cropland. On the other hand, the term ‘natural forest’ was used by both the male and female groups in the interviews to include undisturbed forest, logged over forest and other forest plantations that could be clearly differentiated by the spatial analysis. Local people could not distinguish among different types of natural forest.

In the upstream commune of the Ho Ho sub-watershed, local knowledge confirmed a decrease in the area of annual crops; whereas the opposite result was obtained from the spatial analysis. Most likely, local people only noticed landuse conversion at the smaller, village scale resulting in an incomplete picture of the change in annual crop area at the commune level. However, only through interviews with local people, can drivers of landuse change such as landslides and water scarcity be identified. Interestingly, compared to the men, the women seem to be able to define more specifically the drivers of change for agricultural land such as annual crops and paddy. This is likely related to their daily activities in handling household consumption needs and selling products, so the women are more aware of the transition of agricultural land. We expected a more specific response from the male groups on the change in area of forestry land due to their stronger involvement in forestry business than women. The drivers analysis (Tables 9 and 13) though does not support this hypothesis.

With regard to forests, the local people claimed there had been a decrease in the area of natural forest in the downstream commune. In the spatial analysis, however, the total area of logged over forest increased slightly, but the total area of all types of forests including undisturbed forest and other forest plantation declined during 2000-2014.

In the Huong Khe watershed, the growing population and the plantation forest expansion program of mainly rubber or acacia, were responsible for a massive forest conversion into plantation. In 2000-2014, the total area of rubber monoculture plantation increased dramatically from nothing to 9000 ha. Local people also expanded shifting cultivation with the area of cassava in upland areas increasing by 10 times during 14 years to reach 9740 ha. The area of settlement expanded by 50 percent in 2000-2014. In the Ho Ho sub-watershed, forest conversion into acacia plantation also occurred, especially during the last decade (2000-2014).

Like many other tropical countries, Viet Nam also implements a large-scale afforestation program and devolution of landuse rights, although their impact on enhancing livelihoods and environmental quality is still debated (Clement and Amezaga 2009). Sandewall et al. (2010) claimed the program induced a change in smallholders’ livelihoods from subsistence to a cash-based orientation, diversified the sources of household income, and notably contributed to the landuse mosaic change from the dominating natural forests into farm-based plantations. Particularly in the Ho Ho sub-watershed, a massive conversion of poor natural forests to acacia plantation took place from 2000 due to the afforestation program. Supported by a well-established market-value chain among other supporting factors such as a seedling subsidy and the introduction of N-fixing tree species that could improve soil fertility, farmers converted extensive areas of allocated forest land into acacia plantation. Tree seedlings were initially provided by the government and subsequently local people established their own nurseries. The farmers marketed the timbers to local pulp industries that could absorb the wood supply. Acacia is a fast growing species, with yields harvested generally 6-7 years after planting. Pietrzak (2010) reported that in central Viet Nam, most rural upland villagers did not have secured land tenure, yet they grew acacia trees as part of a long-term livelihood strategy for a variety of benefits, apart from earning income.

Interviews with the local people revealed that the expansion in the forest plantation area through planting acacia will most likely continue steadily into the future, driven by a stable market as well as the good perception the locals have regarding acacia plantation that can presumably provide environmental benefits such as landslide prevention, ability to store soil water and micro-climate regulation. On the other hand, the areas of paddy, which supply the country's main staple food, will most likely continue to decrease along with limiting water availability for irrigation. Local people indirectly foresaw more severe drought will occur in the future and this will suppress landuse systems that largely depend on a regular water supply. A steady decline in forest area was also predicted as a consequence of land conversion into settlements and infrastructure developments.

4. Conclusions

During the last few decades (1990-2014), in the Huong Khe watershed, we noticed a massive conversion of natural forest from undisturbed or logged over forest into rubber or acacia plantation for the pulp industry. The growing population required more lands allocated to sustain livelihoods, and this usually, if not always, involved the allocation of forests land, mostly poor natural forest or logged over forest. The livelihood pressure also induced land conversions into shifting cultivation with maize or cassava or into settlements. In the Ho Ho sub-watershed, a similar pattern was observed. Forest degradation from undisturbed forest into logged over forest prevailed in many areas in the landscape, and due to the afforestation program, we found a large area had been converted from poor natural forest into acacia plantation. This analysis of landcover/use distribution and change is an important element in understanding vulnerability and how the local people view and value tree-based systems and tree planting as a potential solution to enhance livelihoods and environmental resilience in the sub-watershed.

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