

Historical land use dynamics in the Northern mountain of Vietnam

Kim Chi VU¹, Thi Thu Huong HOANG²

¹ VNU – Institute of Vietnamese studies and Development Science

² VNU- University of Science, Hanoi

Abstract: The research has examined the historical land use dynamics in Northern mountain of Vietnam, where is characterised by a remarkable ethnic diversity, mainly living from farming activities. Land use and land cover changes were detected by different techniques: visual interpretation on aerial photos taken from 1952 to 1999 for the case study in a Suoi Muoi catchment in Son La; digital image processing with pixel-based classification on varies Landsat satellite images was applied for Sa Pa, Lao Cai. The results showed in both case studies that increasing land demand led to a significant decrease of the forest and shrub land in favour of upland fields before 1990; and open market and forest protection policies have played an important roles in recently increasing of forest area. Logistic regression techniques were used to detect which variables are correlated with the observed land use change patterns in different case studies. This analysis revealed that both from biophysical parameters such as topography, lithology and cultural factors were significantly correlated with the observed land use change. The results of this research suggested that in order to reach the goal for a sustainable development in such multi-cultural environment, cultural characteristics and development strategies of different ethnic communities should be taken into account.

Keywords: Land use dynamics ,ethnic group, Vietnam

1. Introduction

Over the past decades, land use and land cover changes have been recognized as one of the key driving forces in global environmental changes, which explains why the scientific interest in this subject has been growing. One of the largest programmes was the Land Use and Land Cover Change (LUCC) project, a cooperation between the International Geosphere–Biosphere Programme (IGBP) and the International Human Dimensions of Global Environmental Change Programme (IHDP). The program started in 1993 and lasted until 2005 (Turner et al, 1993). A follow-up Global Land project has started and actively lasted until today. These programmes focus(ed) on different aspects of land use and land cover over the world at both local and global scales.

However, it should be noted that the majority of investigations on land use changes has paid attention to the (bio-) physical factors which determined the spatial pattern of the conversion, while it is well understood that the economical, social and political driving forces induce the majority of land use conversions. The objective of this paper is (i) to study the historical land use dynamics in the two case studies in the North mountain area of Vietnam (Sa Pa district, Lao Cai province and Suoi Muoi catchment, Son La province); and to (ii) detect the variables that control the spatial pattern of change.

2. Materials and Methods

2.1 Study areas

The research paper was carried out in two case studies in the North mountain of Vietnam. The first case study is located in the Suoi Muoi cacthment, Son La province, whereis characteried by a remarkable ethnic diversity (Thai, Khang, Khomu, Kinh, Mong...), mainly living from farming activities. While the

second case study is located in Sa Pa district, Lao Cai province where is also the home of many divered ethnic groups (Yao, Mong, Tay, Day...) and it is famous area for its tourism development (Fig. 1.)

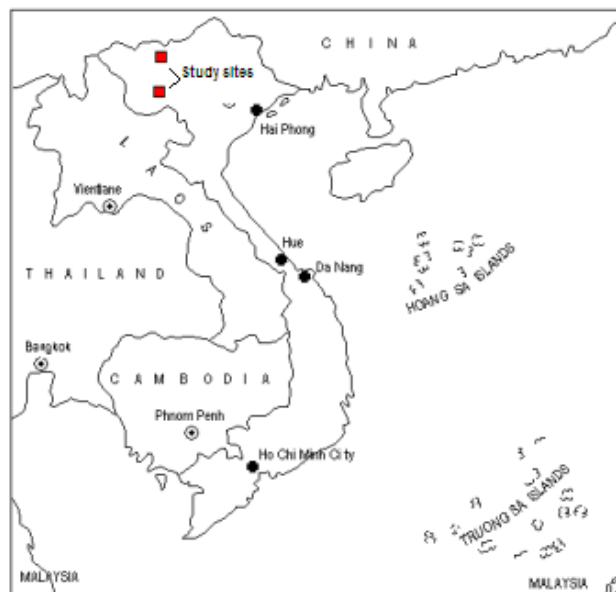


Fig 1. Location of the two study sites

2.2 Data and Methods

Multiple Logistic Regression analysis (MLR) was used to detect possible association between the observed land cover change patterns and the socio-economic and biophysical variables. A multiple logistic regression assesses the probability of a certain event (in these cases: an observed forest/shrub cover change) on a given land unit. MLR is a widely applied technique in land use change analysis as it allows evaluating the combined effect of a range of both categorical and numerical predictors

(Serneels, 2001; Van Dessel et al., 2008; Vanacker et al., 2003; Vu et al., 2013). The equation can then be used to generate spatially-explicit land cover change probability maps

Topographical maps at the scale of 1:50.000 were used to produce different independence variables such as the elevation (m above sea level), the slope gradient (degree), the distance to nearest road (m) and the distance to rivers (m)

Land use/land covers changes since 1954 to 1999 in Suoi Muoi catchment, Son La site were mapped by mean of visual interpretation on the aerial photos. Land use/covers changes in 1993 to 2006 in Sa Pa site were detected by mean of pixel-based classification on Landsat images. In both case studies, land use/land cover information was used as an independence variable for MLR analysis.

A categorical variable 'ethnicity' was determined. A distinction was made between zones that belonged to different ethnic groups as they are not mixed but live in separate villages in both case studies. A map with the territory of each village was, however, not available because village boundaries are not officially registered. The village boundaries were mapped with the help on village heads. In some cases, the territory of each village was approximately delineated by constructing Thiessen polygons around the centre of residential area in each village.

As Sa Pa district is a tourist area, therefore the household data were aggregated at village level, and the following variables were calculated: the percentage of households involved in tourism (%), the population growth rate (%/year), the poverty rate expressed as number of households under the national poverty threshold of 960,000 VND/person/year and the involvement in cardamom cultivation (ha/household).

3. Results

3.1 Observed land use change patterns

a. Suoi Muoi catchment, Son La province

It can clearly be seen that most forest areas (including both closed and open canopy forest) have disappeared in the Suoi Muoi area over the last 50 years. More specifically, the area of closed canopy forest has decreased by 60% between 1954 and 1999 while open canopy forest decreased by 67%. On the other hand, the figures also indicate the expansion of upland field: upland fields have increased by 60 % and rice paddies by 20%. In the same period residential areas also have expanded rapidly. Over the last 50 years, only 35 % of the closed canopy forest has remained intact, while 34% has been transformed to open canopy forest and 22% to shrub. Similarly, only 10 % of the open canopy forest in 1954 has remained: 50% has been converted to shrub land and 30 % to upland fields. There is also a conversion between shrub and upland field: 42% of the shrub land has been converted to upland fields. On the other hand 33% of the upland fields in 1954 were converted to shrub land in 1999. This conversion can be explained due to the long fallow period in traditional farming systems used in the area. After a period of several years of intensive cultivation, the local farmers usually leave their upland fields fallow for four or five years. This custom is commonly found in all the northern mountain areas of Vietnam. Recently, the fallow period has been

shortened because of the lack in upland fields. Farmers try to use their land more intensively and do not leave the land for fallow anymore.

	Area (ha)			Change(%)
	1954	1999	Diff-	1954 - 1999
Closed canopy forest	1146	455	-691	-60
Open canopy forest	3581	1174	-2407	-67
Shrub	13616	11610	-2006	-15
Grass land	1874	1499	-374	-20
Upland field	6825	10932	4106	60
Paddy field	1210	1456	246	20
Residential	123	1246	1123	911
Water bodies		3	3	-

Table 1 Land use in Thuan Chau in the period 1954-1999

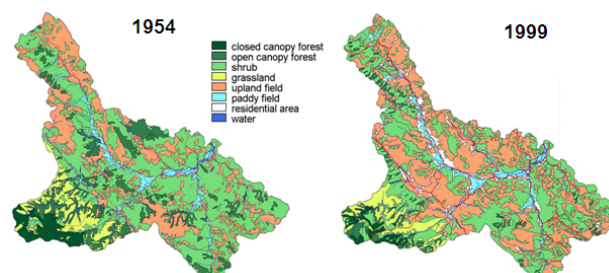


Figure 2. Land use maps in Suoi Muoi catchment, Son La

b. Sa Pa district, Lao Cai province

Figure 3 shows the land cover maps for the years 1993 and 2006. Between 1993 and 2006, the overall area covered by forest and shrubs decreased slightly (with respectively -0.6% and -3.0%) in favor of arable land that increased with +3.6%. Figure 3 shows the spatial pattern of land cover change between 1993 and 2006. Closed canopy forest decreased with 5.6% while open canopy forest area increased with 5.0%. Most of the deforestation took place in the northern part of the district with could be explained by the fact that the forest in the southern part is mainly situated with the Hoang Lien National Park. According to the national law, farmland expansion is forbidden within national parks. Nevertheless, some forest loss can be observed which is probably due to forest fires and illegal logging.

Although the area of rice cultivation on paddy fields decreased with 3.0%, the total cultivated area increased because of a strong increase of the area under other agricultural crops (+6.9%). This shift from the cultivation of rice to other crops is likely caused by the increase in productivity of rice cultivation. From the 1990s onwards, the Vietnamese government has encouraged the use of hybrid rice seeds in combination with chemical fertilizers and pesticides to increase crop yields on the paddy fields and to improve local food security (Bonnin and

Turner. 2012). On average, the yield of rice crops went up from 2.3 ton/ha in 1990 to 4.6 ton/ha in 2010 (GSO. 2010) in Sa Pa district. Once food security was guaranteed, several households diversified their agricultural production with the cultivation of market-oriented crops such as fruits, flowers, and special vegetables such as *Chayote (Sechium edule)*. Besides, breeding of salmon and small cattle such as local pigs and local chicken breeds increased.

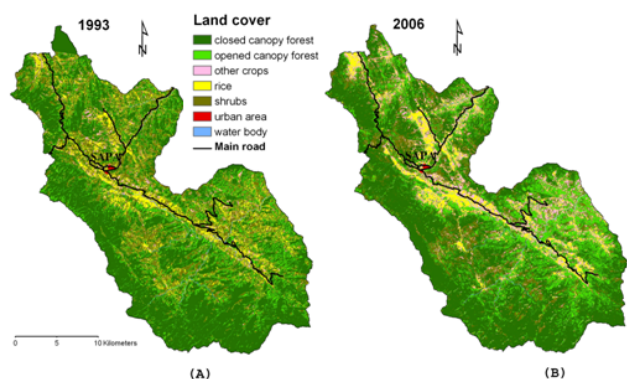


Figure 3. Land use maps in Sa Pa

3.2 Factors controlling land cover change

a. Suoi Muoi catchment, Son La province

The conversion from shrub to upland field is the result of an expansion of agricultural area on the fallow land.

Parameter	Estimate	Standard error	Pr> Chi ²	Odds ratio
Intercept	-7.2621	0.4558	<.0001	
Distance to village	0.00039	0.00016	0.0146	1
Elevation	0.00605	0.0005	<.0001	1.006
Slope	0.041	0.00524	<.0001	1.042
Lithology L1	-1.0292	0.3642	0.0047	0.358
Lithology L3	1.0322	0.2009	<.0001	2.816
Ethnicity E1	0.2604	0.0791	0.001	1.684

$R^2 = 0.2336, \rho^2 = 0.2022$

Table 2. Controlling factors of the conversion from upland field to shrub in the period of 1954 -1999 in Suoi Muoi catchment

The coefficients of the fitted MLR-model for the period 1954-1999 are presented in Table 2. The $R^2 = 0.2336$ and $\rho^2 = 0.2022$ indicate that the model has a significant explanatory value. Upland field-shrub conversion have a higher probability on (1) land units with a basalt or siltstone lithology (L3), (2) land units with a higher elevation and a higher slope gradient, (3) land units that belong to Thai villages (E1).

The analysis above shows that the spatial pattern of shrub-upland field conversion is controlled by both slope gradient and elevation of the land units. Shrub-upland field conversions are more likely to occur on land units with low slope gradients while upland field- shrub conversions are more likely to occur on land units with high slope gradients. This can

be explained by the fact that cultivating steep slopes demands more effort and is less profitable because of processes of soil erosion and land degradation. Moreover steep slopes are in general less accessible for farmers. The expansion of upland fields occurred mainly in the lower parts of the landscape. This can be explained by the fact that the reason can be seen that residential area is often located in the valley near the river course, which is more convenient for the daily life activities. stream, where is more favourable to daily life. Land units at the higher elevations places are often far from the village, which limits the accessibility by farmers. On top of the topographical landscape setting, the spatial pattern of land use changes is controlled by lithology. The land units with sandstone and sandy-clayish-limestone and basalt and siltstone seemed to be favourable for expansion of upland fields. In contrast, land units with schist-siltstone-sandstone and black shale were less favourable for the development of upland fields. This is related to the soil fertility of the different geological units.

Beside the natural factors, the proximity to certain objects also plays an important role as explanatory variable in the calibrated MLR-models. The variable ‘distance to village’ was a significant variable which can be explained by the fact that the land units closer to the village are easier to access which leads to the expansion of upland field nearby the villages. In the long-term transition model, the regression coefficient was positive for both shrub to upland field. This implies THAT more frequently in the remote areas with a poor access to the market. Moreover, in these remote places there land use laws and regulations are not strictly controlled.

The analysis pointed out, for example, that a land unit under shrub has a higher probability of being converted into an upland field when it belongs to a Thai or a Khang village than when it belongs to a Kinh village. This can be explained by the fact that the traditional farming of Thai and Khang is ‘slash and burn’ cultivation, which lead to conversion from shrub to upland field. The Kinh, however, brought the know-how to grow paddy rice from the lowlands and don’t need to practice slash and burn cultivation. Land use models that do not take into account the impact of cultural factors have therefore a lower model performance.

b. Sa Pa district, Lao Cai province

Table 4 shows that the variable household involvement in tourism is negatively correlated with forest degradation. The coefficients of the MLR show that if the involvement of households in tourism is increased with 10%, it is 1.3 times less likely to have forest degradation ($10\% = 10$ unit thus the odds ratio is $e^{-0.0214 \cdot 10} = 0.8$; $1.3 = 1/0.8$).

Parameter	Estimate	Standard error	Pr> Chi ²	Odds ratio
Distance to road	-0.0003	< 0.0001	0.9997	0.0000
Slope	-0.0140	< 0.0001	0.9860	0.0026
Cardamon	-0.1470	0.0290	0.8630	0.0671
Ethnic (Tay)	-0.5750	0.0080	0.5620	0.2180

Table 3. Controlling factors of the deforestation in the period of

1993 - 2006 in Sa Pa district.

Forest degradation is clearly higher in communes in the north and south of Sa Pa district, that are located at greater distance from the tourism center.

Parameter	Estimate	Standard error	Pr> Chi ²	Odds ratio
Tourism Distance to road	-0.0214	0.0030	0.9788	0.0072
Elevation	-0.0002	0.0430	0.9998	0.0001
Slope	-0.0006	0.0003	0.9994	0.0002
Ethnic(Yao)	0.0277	< 0.0001	1.0280	0.0042
	0.3200	0.0460	1.3772	0.1606

Table 4. Controlling factors of forest degradation in the period of 1993 - 2006 in Sa Pa district.

The role of ethnicity is complex. The presence of the Yao ethnic group seems to be associated with forest degradation (Table 4), while deforestation is slowed down in the surroundings of Tay villages (Table 3). This can be explained by differences in geographical residence and livelihood strategy between the ethnic groups. Yao normally settled on steep forested slopes where agricultural extension is limited by topography, while Tay are located in fertile valleys that have good accessibility and are favorable for crop production. Yao normally adopt subsistence agriculture for their survival and need to clear land as a response to rapid population growth (3% per year; (ISODA et al., 2011)). On the contrary, Tay villages are generally more involved in off-farm activities, which are facilitated by their good accessibility to local centers.

The involvement in cardamom cultivation (under forest) slows down deforestation and expansion of cultivated area, as cardamom plantations are not included in the area covered by agricultural lands. Cardamom production results in higher incomes for the local population than traditional crop farming. Recently, cardamom is emerging as an important cash crop in northern Vietnam that requires little investment and labor but may offer relatively high income (Tugault-Lafleur and Turner. 2009). The national government allows local households to grow cardamom in the forest of national parks. Its impact on forest conservation is similar to the system of shade coffee cultivation in forest that also contributed to a preservation of the afro-montane forests in e.g. the south of Ethiopia (Getahun et al., 2013).

4. Discussions

In Vietnam, the rapid increase in forest area since the early 1990s resulted in a reversal of the national deforestation trend (Meyfroidt and Lambin. 2008a). The national-scale assessment masks a wide range of other land use dynamics that exist at the local scale, and that are not necessarily conform to the overall trends in forest cover change at national scale.

In the case in Suoi Muoi catchment, the major land use dynamics in the Suoi Muoi catchment are conversions between shrub land and upland field in both directions whereby the conversion from shrub land to upland field is dominant. A

detailed spatial analysis of these changes showed that the spatial pattern of these transitions is related to natural factors such topography and lithology. Shrub-upland field conversions are more likely to occur on land units with low slope gradients. This can be explained by the fact that cultivating steep slopes demands more effort and is less profitable because of processes of soil erosion and land degradation. Moreover steep slopes are in general less accessible for farmers that carry farming tools. Apart from slope gradient, land use change probabilities are also dependent from the elevation of a land unit. Land units at higher elevations are often far from the village, which limits the accessibility by farmers. Therefore, it rather tends to leave it as shrub area. On top of and the topographical setting, the spatial pattern of land use changes is controlled by lithology. The land units with sandstone and sandy-clayish-limestone and basalt and siltstone seemed to be favourable for expansion of upland fields. In contrast, land units with schist-siltstone-sandstone and black shale were less favourable for the development of upland fields. This is related to the soil fertility of the different geological units. Basalt and limestone are the most suitable land for upland crops. The analysis pointed out, for example, that a land unit under shrub has a higher probability of being converted into an upland field when it belongs to a Thai or a Khang village than when it belongs to a Kinh village. This can be explained by the fact that the traditional farming of Thai and Khang is 'slash and burn' cultivation, which leads to conversion from shrub to upland field. The Kinh, however, brought the know-how to grow paddy rice from the lowlands and do not need to practice slash and burn cultivation. Land use models that do not take into account the impact of cultural factors have therefore a lower model performance

In the Sa Pa district, there is a wide variety of human-induced change in forest cover despite the net loss in forest area between 1993 and 2006. Forest cover dynamics are different in villages that are strongly involved in tourism activities. They are characterized by significantly higher rates of land abandonment and lower rates of forest degradation. This can be explained by recent changes in labor division and income in rural households. In the traditional ethnic society, labor was mainly divided by gender (Duong. 2008). Traditionally, women managed the household, planted and harvested rice while men were in charge of the heavy works such as logging, plowing and processing jewelry and tools (Cooper. 1984; Symonds. 2004). This traditional labor division was challenged by the rapid growth of the tourism industry in Sa Pa town (Michaud and Turner. 2000). The development of tourism activities mainly offered new off-farm opportunities for women from ethnic minorities, having as a direct consequence that men are now more involved into household management (Michaud and Turner. 2006). As there is less manpower available for agricultural activities, land preparation involving cutting or clearing of trees is strongly reduced. However, tourism development not necessarily leads to a decrease of the pressure on land. The presence of alternative income sources can also drive the intensification of agricultural production through hired rural labour and/or the expansion of the cultivated area through

land purchase. This is illustrated by the study of Forsyth (1995) for northern Thailand that clearly showed that tourism development did not cause a decrease of the pressure on forest and soil resources. These studies show that local and national land use policy likely plays an important role in directing tourism development towards sustainable natural resource management.

5. Conclusions

The objective of this research was the identification and understanding of the driving and controlling factors of land use change in North mountain of Vietnam. Land use and land use change are often examined by means of remote sensing, including aerial photos and satellite images. Social scientists on the other hand developed a set of longitudinal and panel analysis techniques to get a grip on the temporal evolution of micro-societies at different geographical levels (Axinn and Barber, 2003; Rindfuss et al., 2003; Holling et al., 2002). At present however, very few studies have attempted to link spatial datasets with social databases. In this study “Ethnicity” is considered to be a categorical variable that describes population groups, which are homogeneous in terms of socio-cultural background, lifestyle and farming practices.

By means of statistical analysis, a number of independent variables that are correlated with the spatial pattern of land use and land use change were identified for two case studies: Suoi Muoi catchment and Sa Pa district. The distance to road appeared to be highly correlated with the degree of agricultural intensification. This could be explained by the fact that the distance to the road can be considered as a proxy variable for market accessibility. In villages with a good access to the market, new technologies such as the introduction of new plant varieties, the use of fertilizers and pesticides are more easily adopted. Next, a range of environmental variables such as slope gradient, elevation and lithology could be linked with the observed patterns of land use change. The variable “ethnicity” appeared to be a significant factor in all MLR models. These findings are important and could be integrated in multilevel approaches in order to get a better grip on the role of socio-cultural factors in land use change processes at various scale levels. The results of this research suggested that in order to reach the goal for a sustainable development in such multi-cultural environment, cultural characteristics and development strategies of different ethnic communities are very important drivers that must be taken into account in the study of land use change. On top of that, Land policies and the influence of open market or tourist development always play an important role for the sustainable developments.

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