Landscape changes in *Cho Don* District during the *doi moi* era (1990-2000) and their implications for sustainable natural resource management in *Viet Nam*'s mountainous provinces

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Abstract

The mountainous zones of northern *Viet Nam* have been mostly bypassed by the remarkable economic growth that delta regions have enjoyed in recent decades. The extreme diversity within these remote mountainous zones causes national policies to have vastly different outcomes in different areas, even within the same province or district. In this chapter, we examine the relationships between the biophysical and socioeconomic factors that shape peoples' livelihood strategies and, ultimately, their standards of living.

We combine a broad district-level geographic approach with localized monographic studies to assess the effect of geographic conditions on rural development. After identifying the village as the elementary unit of natural resource management, we demonstrate that biophysical characteristics (landscape, relief, climate) are the defining factors behind village production systems. Villages that have production systems based on wide valley bottoms cropped with irrigated rice tend to be compact and accessible. In contrast, villages in steeply-sloped forested areas tend to be spread out and inaccessible. The *doi moi* reforms of the 1980s and 1990s have mostly benefited the former type of villages, populated mostly by the *Tày* and *Kinh* ethnic groups, while leaving behind the latter type, mostly *Dao* and *H'mong*. The geographic approach offers researchers a mechanism for classifying and identifying the villages in greatest need of technical assistance without the need for exhaustive monographic studies.

Keywords: land use changes, resource use, mountain agriculture, accessibility, *Viet Nam*

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1. Introduction

1.1. Poverty and natural resource management in the mountains of northern Viet Nam

The mountainous regions of northern *Viet Nam* are today receiving particular attention from the national government, as they have thus far missed out on the impressive economic development that has blessed the rest of the country since the *doi moi* reforms that began in the late 1980s (Jamieson et al., 1998; Dao The Tuan, 2000). Today, about fifteen years into the reform process, the national poverty level has dropped from 58% to 37%, but remains at 60% in the northern mountains (Poverty Task Force, 1999). In the relatively inaccessible mountainous provinces, many village economies are based exclusively on subsistence agriculture and depend directly on the availability of natural resources to farmers. The mountainous regions are characterized by great ecological diversity, which can lead to substantial disparities in resource availability within even a small area. Low availability of natural resources is a major criterion for the State in identifying disadvantaged areas (CEMMA, 1997). Further, poverty reduction programs often target villages based on their isolation, their weak infrastructures, and their level of environmental degradation (Minot and Baulch, 2002). Underlying these criteria is an implicit relationship between poverty and the environment that is rarely documented in the literature (Le Trong Cuc and Rambo, 2001). In this chapter, we will examine this relationship and evaluate the relative roles of biophysical and socioeconomic factors in the recent agricultural changes that have visited the mountainous regions.

Near the end of the 1980s, some researchers predicted major environmental destruction in the northern mountains including *Bac Kan* Province (Dang Dinh Quang, 1991; Piquet and Puvilland, 1992; Dao The Anh and Jesus, 1993). Several years later, however, new land policies and the prohibition of slash-and-burn systems resulted in a visible improvement in forest cover (Sadoulet et al., 2002; Castella et al., 2002b). Land allocation to individual households had stabilized the livelihoods of most farmers in the region by creating incentives for paddyland cultivation and agroforestry. But some farmers slipped through the cracks. Those who did not receive paddyfields in the land allocation were forced to return to unsustainable slash-and-burn systems on the hillsides (Castella et al., 2002). Rural development in *Bac Kan* Province needs to focus on reaching the most marginalized groups who thus far have been neglected by the development process. Geography has played an important role in keeping these poorest of farmers on the periphery of development and needs to be considered in identifying intervention points to assist them. In this chapter, we will demonstrate the role that geography has played, and show how researchers can use broad geographic techniques to identify priority areas for future development interventions.

1.2. Land use changes and the complex human and natural environment

In examining the natural resources of a region, it is important to consider both biophysical characteristics that remain unchanged over long periods (geology, soil types, climate, etc.) and the comparatively rapid-changing (on the order of several years) ways in which communities use resources. Our research rests on the understanding that there is no equilibrium state of an agricultural landscape, but rather, evolution patterns that may be positive or negative in terms of long-term ecosystem sustainability. The resource situation at any given date is in a state of flux, and is the result of past land-use changes and natural resource management approaches.

The evolution of land use and of natural resource management approaches is shaped by State policy. A single agricultural policy applied broadly to the heterogeneous mountain zones, where one valley can differ markedly from the next, can result in a diversity of localized effects. For example, the land allocation policies of the reform period were reinterpreted and adapted in a wide variety of ways across the mountains (Castella et al., 2001). The successive reforms of *Doi moi*, each interpreted and then reinterpreted at various levels, further contributed to the present complexity. As a result, the simple criteria (i.e., ethnicity, rich/average/poor households) used by State institutions to classify communes and villages are no longer sufficient (Minot and Baulch, 2002). To guide development activities, the present diversity needs to be understood both in terms of its present-day spatial characteristics and projected evolution patterns in the future.

Landscapes and their natural resources are shaped by the land uses of the populations that base their livelihoods on those resources. Completing the circle, farmers develop their production strategies based on the way they perceive their environment, and their social and economic conditions are often determined by resource access.

With remote sensing technology, we can follow the evolution of landscapes, thereby gaining insight into local biophysical and socioeconomic processes. In this research, our first objective was to characterize the diversity of landscapes in *Cho Don* District of *Bac Kan* Province in terms of biophysical parameters, and then to describe the landscapes' evolution based on a chronological series of land-use maps. Moving down to the village scale, our second objective was to associate the key biophysical parameters with farmers' practices and the socioeconomic variables that affect those practices. The third objective was to analyze the interactions between these static (biophysical) and dynamic (human) variables, to create a typology of villages in *Cho Don* District. From this typology, we can classify local circumstances and recent evolution patterns, bringing to light the most crucial intervention points for development.

2. Methods

2.1. Theoretical framework

Our methodology was guided by the hypothesis that landscape changes are the result of interactions among (i) spatial organization of natural resources, (ii) quality or condition of natural resources, and (iii) local rules for natural resource management. Figure 1 demonstrates the functional relationships between these biophysical and socioeconomic parameters.

With the goal of encompassing the whole of *Cho Don* District in our survey, we developed a geographic information system (GIS) with information at the highest level of detail available (described in section 2.2). This GIS included two kinds of data: (i) static data, which have not substantially changed in the last ten years: hydrology, soil types, geomorphology, etc.; and (ii) data for dynamic variables: land use, population, accessibility, etc.. The joining of these variables in the GIS allowed a broad characterization of natural landscapes.

After examining the structural and functional relationships among landscapes and the other layers of the GIS, we tried to relate these relationships to local land uses and stakeholders' decision-making processes. With the active participation of local informants, we associated data from monographic surveys with information from a chronological series of aerial photographs, helping us to understand local rules for natural resource management and their impact on the environment. We focused particularly on local stakeholders' perceptions of the resources available to them, and the ways in which these perceptions influenced stakeholders' final decisions about production strategies. This participatory approach had to be limited in its spatial coverage, and did not go beyond the village level, but was undertaken in a number of villages that were deemed to be representative of the entire province. With the help of the GIS, we selected a group of research sites that encompassed the provincial diversity of agro-ecological systems and levels of accessibility.

Monographic studies conducted in *Cho Don* District proved that the village, corresponding to a micro-watershed in geographic terms, was the elementary unit of natural resource management (Mellac, 2000; Castella et al., 2002a and 2002d). At the village level, we examined the impact of both internal and external factors on the already-identified landscape changes. We studied the statistical relationships between socioeconomic and geographic variables through principal component analyses. The monographic studies then helped us to interpret the statistical results and formulate hypotheses about natural resource management rules in the different types of villages that we identified. The study culminated in a typology of village agro-ecosystems, which allows us to target recommendations to match the kinds of problems encountered in each kind of village.

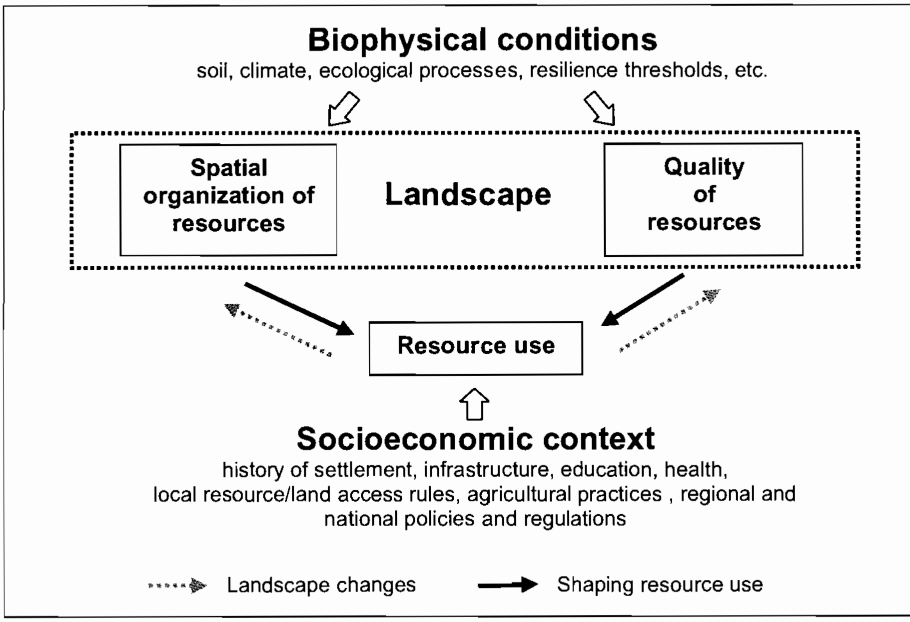


Figure 1: *Interactions to consider when analyzing landscape changes*

2.2. Data sources

Quantitative geographic data

Static biophysical characteristics. The maps representing the main biophysical variables were drawn from a provincial database of information from various institutions and projects (Brabant et al., 1999). The soil map of the district was created by Raunet (1999).

Land use maps. Cho Don District has been the subject of several research programs (Bal et al., 1997; Brabant et al., 1999; Mellac, 2000), and several land use maps were available. However, we used them as ancillary data because they were not available at the same resolution, did not all describe the same information, and did not have consistent legends. We developed a consistent series of land use maps at the maximum resolution available from the SPOT satellite images for three successive dates: 1990, 1995, and 1998.

Socioeconomic survey of Cho Don villages. In 2000, we surveyed all the villages in the district, evaluating their access to different kind of facilities (markets, schools, and health services). In each of the twenty-two communes, we organized meetings attended by all of the commune's village heads. In each meeting, we presented a topographic commune map on which the village heads traced their village boundaries. The commune is the smallest administrative entity recognized by the State (and the lowest level at which statistics are available), but it was important to identify village boundaries if we were to evaluate the state of available resources at the village scale.

We then asked the village heads to draw existing roads and paths on the maps and identify travel times on routes of varying qualities. We processed travel times from villages to different locations (facilities, main towns, other villages, etc.) with the GIS tools FlowMap® (Zwakhals et al., 2000) and ArcView® (Ormsby et al., 1998) to generate accessibility indicators (e.g. isolation, remoteness). This information was merged with socioeconomic data for each of the 231 villages in the district, including population, proportion of households of each ethnicity, illiteracy rates, poverty levels, date of access to electricity, schools, presence of markets, health services, modes of access to information (number of televisions, radios, telephones), and type of animal husbandry (buffaloes, cows, pigs).

Qualitative geographic data

Monographic Studies were undertaken by university students over a ten-year period in several communes of *Cho Don* (Dang Dinh Quang, 1991; Piquet et Puvilland, 1992; Mellac, 2000; Castella et al., 2002c; Eguienta et al., 2002), resulting in a large database of information on diverse sites that represented the diversity of the district (e.g. agrarian history, natural resource use by the various ethnic groups, production strategies, etc.). In 1999 and 2000, a monographic study conducted in *Ngoc Phai* Commune (Castella et al., 2002c) confirmed that the factors influencing the agrarian history of *Cho Don* District were also at play in other districts of *Bac Kan* Province (Sadoulet et al., 2002; Castella et al., 2002b; Fatoux et al., 2002; Alther et al., 2002). Moreover, we used a chronological series of land use maps to characterize the evolution of the landscape in the studied communes over the last five decades (1950-2000). We then used the monographic studies to help explain the observed changes in land use.

Analysis of village-level resource use. We addressed the spatial dimension of resource use in *Phieng Lieng* village, *Ngoc Phai* Commune, where agrarian history was representative of a large number of *Tày* villages in the district (Castella et al., 2002d, Eguienta et al., 2002). Using a visual relief model of the village, we discussed with local farmers the seasonality and locations of agricultural activities (cropping, animal husbandry) and forest product gathering. This mix of interdisciplinary scientific data (maps derived from aerial photos, biomass measurements, etc.) with local understanding and perceptions allowed us, together with the villagers, to evaluate the impact of various production practices on the natural resource base (Castella et al., 2002a; 2002d).

The qualitative data made it possible to analyze the functional relationships among the quantitative variables introduced earlier: static biophysical characteristics; village-level socioeconomic data from a single date, 2000; and the succession of landscapes from the 1990, 1995, and 1998 land use maps.

3. The landscapes of *Cho Don* District

3.1. Biophysical characteristics and distribution of natural resources

North-South biophysical diversity

Approximately 900 km² in size, *Cho Don* District is in a transition zone between the Red River Delta and the northern mountain chain. The district spans altitudes from 200m to 1500m (Figure 2-A), although more than half of it is below 400m. The district can be subdivided into three main geomorphologic zones that lie along a north-south geomorphologic gradient (Figure 2-B).

- The **southern zone** of the district is composed of gentle hills (20 to 60m in height), surrounded by a network of rivers and small valleys with flatland areas suitable for wet-rice cultivation.. The soils in this zone are thick (100-200 cm), resting on a substrate of quartzite and schist.
- The altitude of the southern zone rises toward the north, leading to the **central zone**, made up of high hills. Reaching to 700m in altitude, the high, steeply sloping hills average about 80-200m in altitude. Like the southern zone, this zone rests on schist and quartzite. The relief makes for clearly defined watersheds (Mellac, 2000).
- Further north, past the district administrative center of *Bang Lung*, the landscape becomes mountainous. In this **northern zone** the relief is strikingly marked by sharp crests, steep slopes, and boxed-in valleys, making for very clearly defined watersheds (Raunet, 1999). Two massifs rise above 1000m in the northern end of the district. Climate is cooler at the higher altitudes, with average temperatures 4°C colder than in the southern zone (Brabant et al., 1999). In this schist-dominated zone, granite and limestone outcroppings make up the highest mountains. Soil depth varies widely (0-100 cm).

These three geomorphologic zones are scored by alluvial valleys, the largest of which have deep soils and are often marked by high terraces. These terraces dominate the valleys, and are composed of ancient alluvia lying on schist and covered by colluvium from the surrounding slopes. Five major rivers wind through these valleys, defining the major watersheds of the district (Figure 2-C). Of particular interest are the *Song Pho Day* and *Khuoi Vao* valleys, which make up the major transport corridor in the north of the district.

Distribution of natural resources

The *Cho Don* land-use map is composed of six land classes:

- *Cultivated land*: **paddyfields** are located in the valley-bottoms and on terraces. **Upland crops** is used on our land use maps both for bare soil and for hillsides covered with non-woody vegetation (crops, crop residues). **Lower hillside**

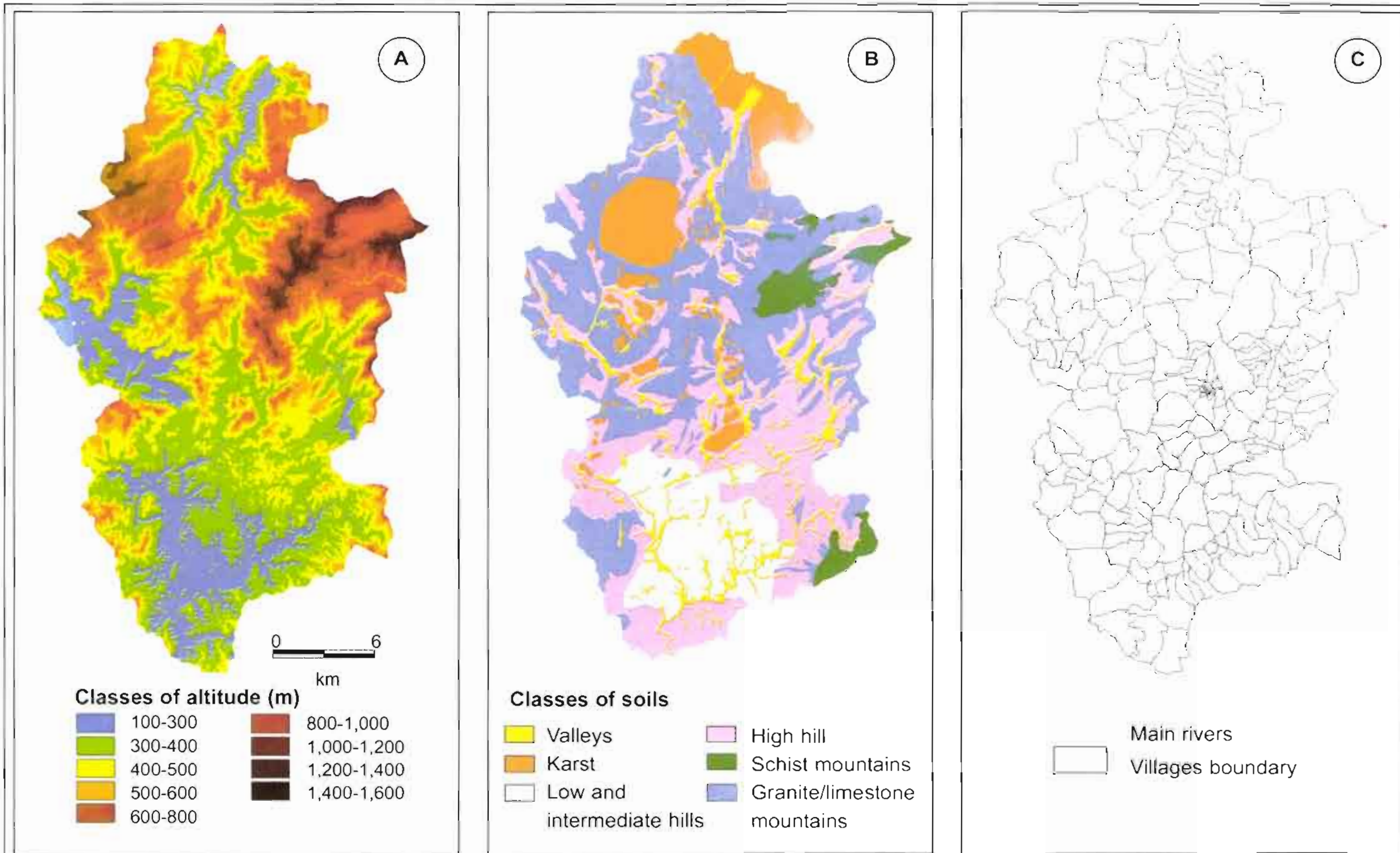


Figure 2: *Maps of Cho Don District. A: topography, B: geomorphology, C: hydrology and village boundaries.*

mosaics are intensive mixed cropping located near houses and paddyfields in the intermediate zone between upland and lowland crops.

- *Uncultivated land*: **shrubland** corresponds to areas covered by woody plants less than 5m high with medium to high densities, and may have an herbaceous stratum. The difference between shrubland and open forest can be hazy, and a given area could change classes depending on the season in which the satellite image was taken (October in 1990, December in 1995, and September in 1998). We used a single class **forest** for all forests to account for seasonal variations that could affect our forest cover statistics (e.g. trees losing leaves). Our definition of a forest is therefore rather broad, covering any trees higher than 5m, with medium to high densities.
- *Residential zones*: **residential areas** were delimited with the help of aerial photographs.

The 1998 *Cho Don* land-use map (Figure 5) shows a distribution of natural resources at the district level that varies with the toposequence (lowland, hillside, hilltops).

Paddyfields are concentrated in the wide, flat lowlands of three river valleys to the north and east, and nestled between the low hills of the southern zone. In the north of the district, the lower hillside mosaics are found mostly at the bottom of the colluvium slopes and on the edges of large lowland paddyfield areas. In the southern zone, the area of lower hillside mosaic is more limited, concentrated around the smaller paddyfields and at the bottoms of steeper slopes. The hillsides are the setting for a variety of crops and plants representing a series of stages of forest regeneration in the slash-and-burn cultivation process. Cropped fields on the hillsides are most often cleared from forested areas, and then abandoned when soil fertility declines. Years of fallow allow secondary forest to grow. Shrubland is an intermediate phase in the cultivation process, often marked by bamboo competing with mixed woody species. Bamboo is classified as a pioneer species after forest fire, often indicative of forest deterioration (Mellac, 2000).

Secondary forests are found on the highest summits and steepest slopes, particularly on the two northern massifs, the least accessible of areas. Their specific ecological conditions (limestone substrate, high altitude, and harsh climate) have selected particular plant species. These summits are covered by evergreen forest, also found in the far north of the district on limestone soils. Lower altitudes are populated by semi-deciduous forests or in some locations covered by bamboo forest (Mellac, 2000).

The spatial variability of natural resources in the district is thus determined by the north-south geomorphologic gradient. We can summarize this variability as follows:

(i) in the north, mosaic-covered hillsides extending between two unchanging land-cover classes: paddyfields on lowlands, and forests on top of high summits and steep slopes; and

(ii) in the south, a landscape with intermingled land-cover classes.

3.2. The agro-ecological diversity of Cho Don villages

The territory of a village is most often defined by a small watershed that drains rainfall into streams that run into a river at the bottom of the valley, where paddyfields are often located. The intensity of land use increases as one progresses from the mountains at the top of the watershed toward the houses and paddyfields at the bottom. Houses tend to be strung along a road or path that runs past the central paddyfields. Gardens and orchards are found close to the houses on colluvium at the bottoms of hillsides. Above the gardens, intensive upland crops are grown on the lower hillsides (mostly maize and cassava for feeding pigs and fowl), characterized by short fallow periods and use of chemical inputs. Orchards also extend into these lower hillsides as they are protected against theft by the proximity of houses. On the higher hillsides of the watershed, far from houses, is a combination of cropped fields and areas of natural plants. Long fallow periods here take the place of fertilizers in restoring soil fertility. The fallow fields in this zone are the most common place for grazing ruminants (buffaloes and cows). It is also in the upper levels of the watershed that farmers gather forest products (timber for heating and construction, bamboo shoots, edible leaves, mushrooms, and medicinal plants).

Biophysical conditions vary across the district, and a village's location largely determines the principal land use of that village. To classify village agro-ecosystems, we extracted statistical variables (area and number of polygons of each land use class, average distance of each land use type, etc.) from the maps presented above and entered data for 231 villages into a non-geographic database. We then used 222 of these villages for a statistical analysis. The nine excluded villages were residential sections of *Bang Lung* town, the district administrative center, whose small sizes made it impossible to generate geographic data at the level of detail required for our analysis.

A principal component analysis (PCA) of 1998 data on land use, soil classes, slope inclinations, and altitude variations allowed us to distinguish the various classes of villages in *Cho Don* District. The PCA revealed (not surprisingly) that villages with gentle slope inclinations tend to be based on paddy production, whereas villages with steep gradients tend to be based on upland cultivation and agroforestry. The PCA also showed that the latter villages have surface areas much larger than the former, highlighting the importance of paddyland in structuring village space (Figure 3).

The PCA made it possible to identify four main classes of village spatial organization. Figure 4 shows the land classes of an average village in each defined class. Types I and IV represent only a small proportion of villages (7%

and 3%, respectively), whereas types II and III respectively encompass 60% and 30% of the villages in the district. Type I villages are characterized by their very small surface area and the high proportion covered by the residential zone; these are urbanized villages on the periphery of *Bang Lung*. Type IV villages have a

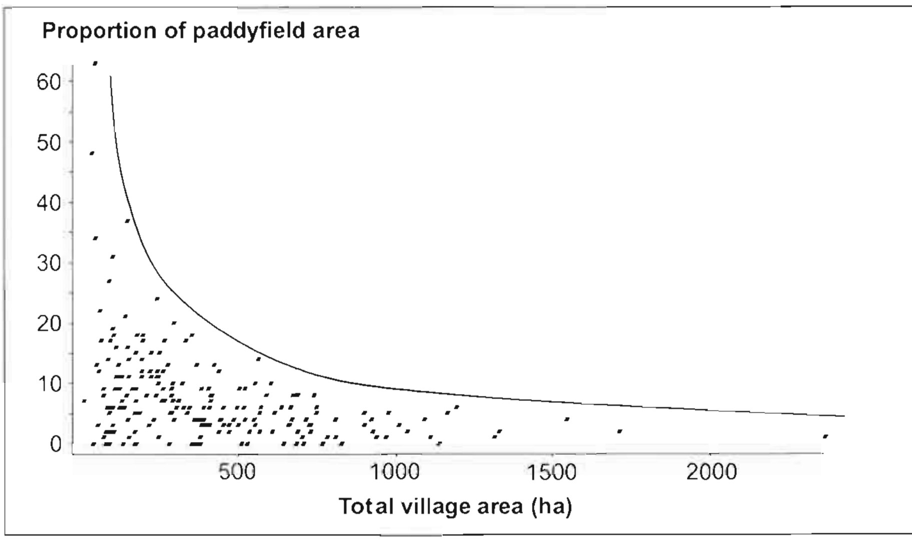


Figure 3: *Relationship between Cho Don village surface area and the proportion of that area covered with paddyfields*

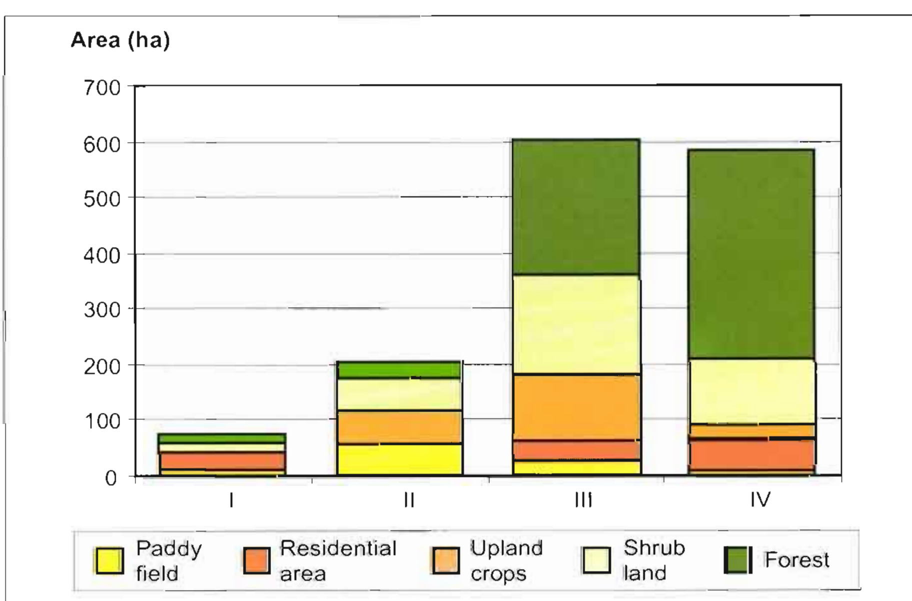


Figure 4: *Graphic representation of the four types of village spatial organization*

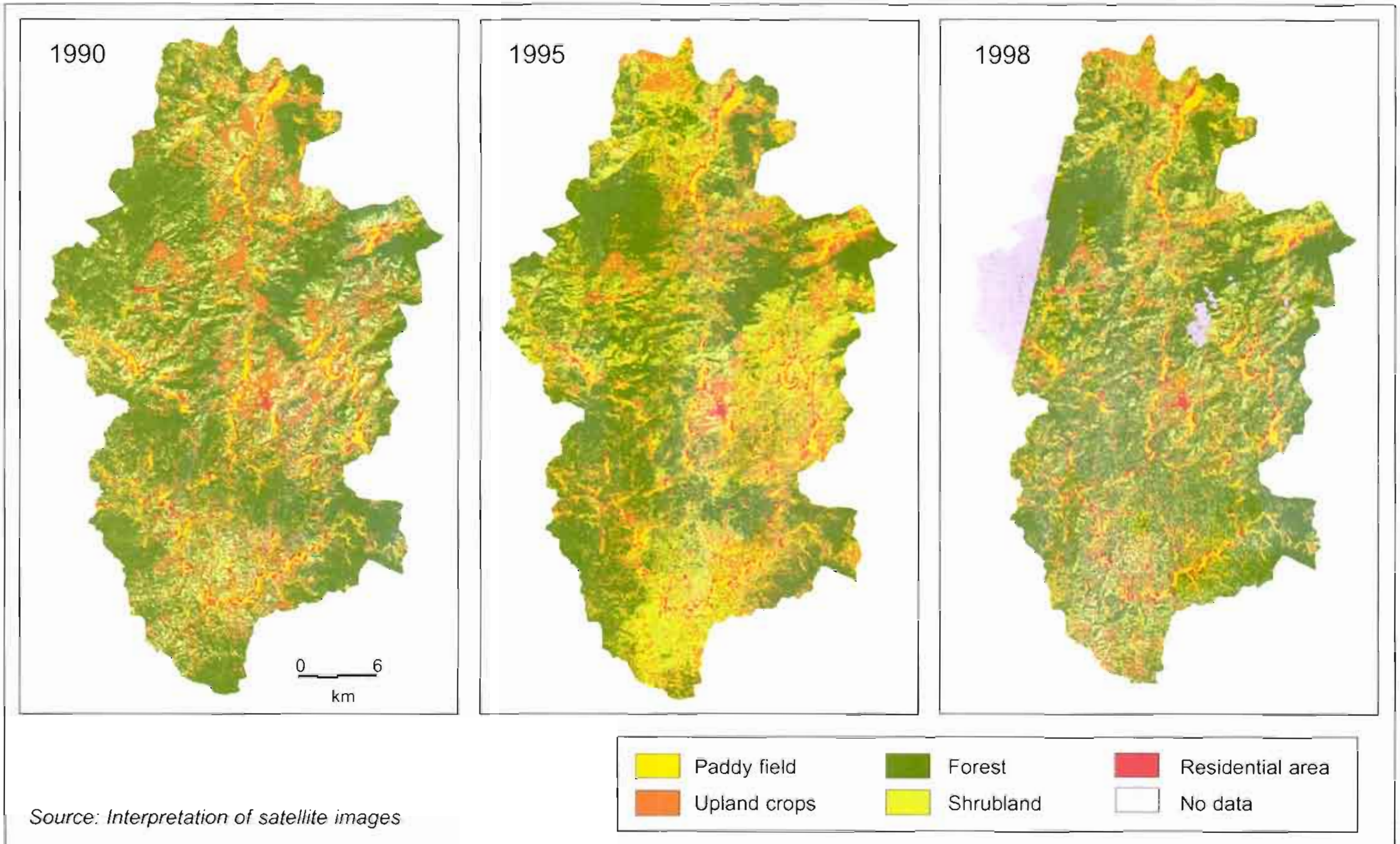
very small amount of agricultural land, and large residential and natural-vegetation areas; these villages are in a military zone and an area near a mine, where inhabitants do not rely on natural resources. Type II villages are small but enjoy high proportions of paddyland, whereas Type III villages are considerably larger and rely on extensive hillside cultivation. Our study focuses on these two village types and their very dissimilar spatial organizations.

4. Landscape changes and natural resource use

Following twenty-five years of collectivization, the land policies of the 1990's marked the beginning of a period of changing access to natural resources. We placed 1998 land use into historical perspective by comparing it with land use at previous dates in the same decade. We sought to explain the landscape of 1998 by analyzing changes in plant cover from *Cho Don* land-use maps from 1990 and 1995 (Figure 5). 1995 was the year that all forestlands were allocated to individuals in *Cho Don*, making it an interesting middle date for this analysis. In our analysis, we did not include the land classes that remained nearly constant at the district level over this period, these classes mainly being paddyfields, lower hillside mosaics, and residential areas. Simple variables allowed us to follow land cover change: (i) the proportions of land-use classes from 1990, 1995 and 1998 (Figure 6); (ii) the average area and number of upland crops fields (Figure 7); (iii) the proportions of each major class that remained stable across all three dates (Figure 8); and (iv) the changes in those classes across the three dates (Figure 9).

Although the **1990** land use maps show as much forest as the **1998** maps (Figure 6), in 1990 that forest was substantially fragmented by upland crops, which occupied 13% of the district. Extensive shrub zones in the north covered wide clearings (15 ha on average), whereas shrubland in the South was in clearings that were smaller (average 10 ha) and less numerous (Figure 7). In 1990, the total area occupied by crops (including paddyfields, mosaics, and upland crops) was equal to that covered by shrubs (23%).

In **1995**, district forest cover attained what would be its lowest level in ten years, 39% of district area, even though upland crop area had slightly decreased since 1990, a decrease that continued in 1998 (Figure 6). In 1995, the average size of a cropped upland field was only half as large as in 1990. However, the number of fields had nearly doubled, and they continued to occupy 12% of district area (Figure 7). These fields were scattered over the hillsides, concentrated to some degree in the north but much more spread out than they had been in 1990. There was more shrubland in this period (30%) than in either 1990 or 1998 (Figure 6). In 1995, shrubland was primarily land regenerating after having been cropped in 1990, but also included several large areas of recently cleared forest. Between 1990 and 1995, we can therefore see that new fields were cleared from forests



Source: Interpretation of satellite images

Figure 5: *Land use maps, Cho Don District, 1990, 1995, and 1998*

(41% of the total area of upland crops), but also some from shrubland (Figure 9-A).

In **1998**, forest cover had returned to 1990 levels (Figure 6). In spite of its fluctuations, the forest is the most stable land class (Figure 8), particularly in the inaccessible zones of the northern massifs and high hills in the center and the west. The surface area of upland crops continued to decline, reaching its lowest level in eight years (8%). Since 1995, these fields had decreased in number but increased in average size and moved nearer to the valley-bottoms.

The evolution of the land that was covered by upland crops in 1990 clearly shows the regeneration process and regular relocation of upland crops, because by 1998, 76% of that land was classified either as forest or shrubland (Figure 9-B). Shrubland remained abundant in 1998 (27%), even if it had declined somewhat since 1995 (Figure 6). Shrubland usually represents land that is regenerating after having been cultivated, but the dynamic view reveals a more complex picture. Figure 8 shows that shrubland is fairly stable (45% unchanged over the eight years), which suggests that this land class may be the final degenerated state of plant cover; i.e. it may never regenerate into forest. Crops

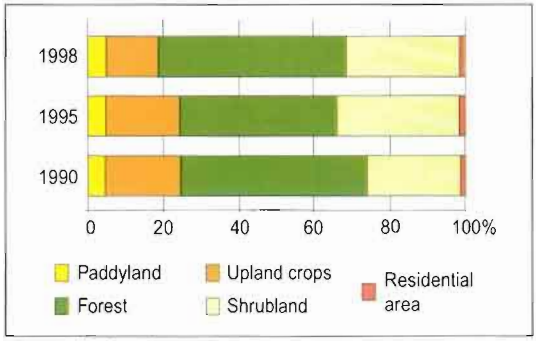


Figure 6: *Land-use class proportions in 1990, 1995, and 1998*

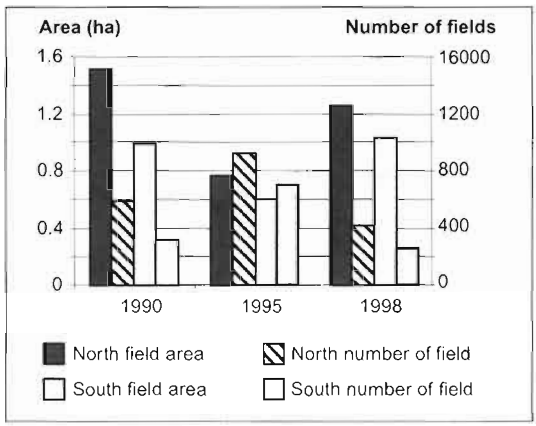


Figure 7: *Average size and total number of cropped upland fields in 1990, 1995, and 1998*

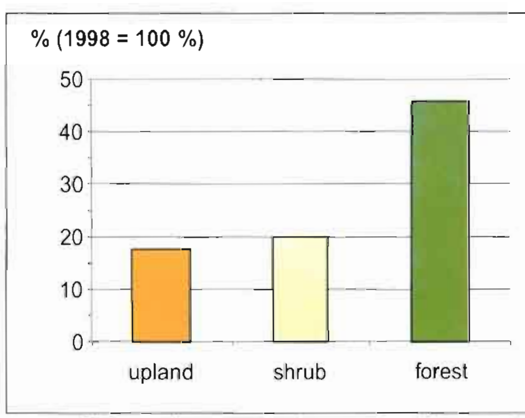


Figure 8: *Proportion of upland crops, shrubland, and forest that was stable across all three dates (1998=100%)*

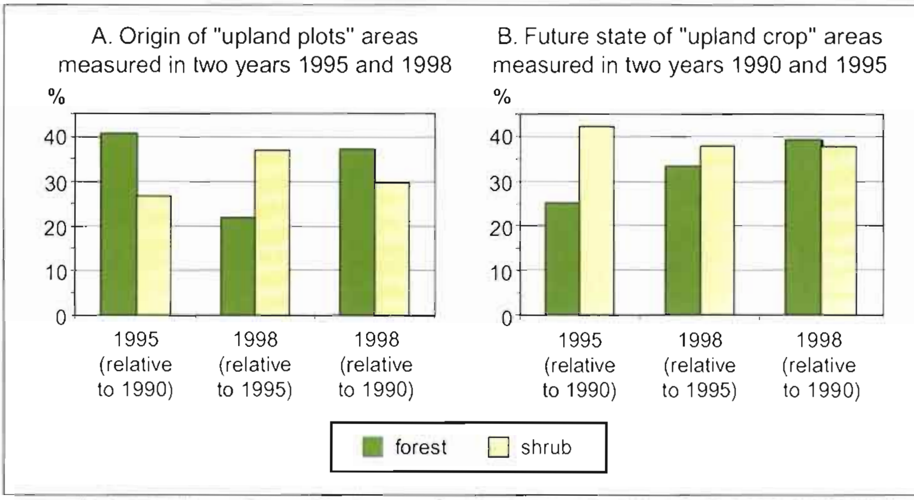


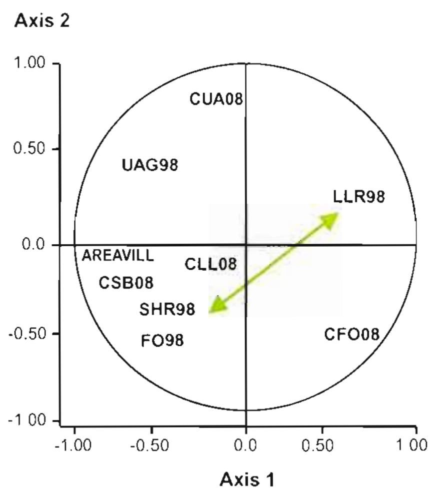
Figure 9: *Origin (A) and future (B) of cropped upland plots between sets of dates, 1990-1995, 1995-1998, 1990-1998*

N.B.: Reading example for graph A: Of all the area covered by "upland crop" land class in 1995, 41% had been "forest" in 1990 and 26% had been "shrubland" in 1990. For graph B: Of all the area covered by "upland crop" land use class in 1990, 25% became "forest" in 1995 and 42% became "shrubland" in 1995.

planted on cleared fields can sometimes cause an irremediable loss of fertility, particularly in areas of steep slopes and shallow soils in the north of the district. In these areas, the forest may never grow back. It is also possible that these shrublands are not regenerating because of bamboo harvesting. Shrubland can also represent cleared forest (a deterioration in quality) caused by wood harvesting.

The landscape dynamics were characterized at the village level through PCA analysis. Using data extracted from the three land-use maps (Figure 5), we calculated the land-use changes for each land class in every village for every pair of dates (90-95, 95-98, 90-98), thus obtaining new variables describing the positive or negative change in the area of forest, shrubland, paddyfield and upland crops. We then integrated these variables with the static land-use data for 1998 in a new PCA. The PCA results presented Figure 10 and Figure 11 show that the new allocation policy had an immediate impact on land use, one that was statistically significant even in a span of only three years (1995-1998). However, the effects of the allocation on forest clearing were substantially different across different villages. Before 1995, the expansion of upland crops took the form of large clusters of fields cleared in the free-access forestland managed collectively by several families. This characteristic forest-clearing pattern took place primarily in villages based on irrigated ricefields. After 1995, the upland fields became smaller and more dispersed within the now-fragmented forest, especially in forest/upland-based villages. After the 1995 land allocation, we can see increases in forest cover in villages of the former group, but forest decreases in the latter group. This observation is consistent with results obtained from monographic studies that examined the relationships between rice-growers and swidden cultivators and their natural environments (Castella et al., 2002b and 2002d).

As we have seen, the purely spatial approach allows us to observe the changes in land use and resource organization in the district over a period of time. However, because land use is shaped by the natural resource management practices of local populations, better comprehension requires the study of the underlying practices.



Variable names:

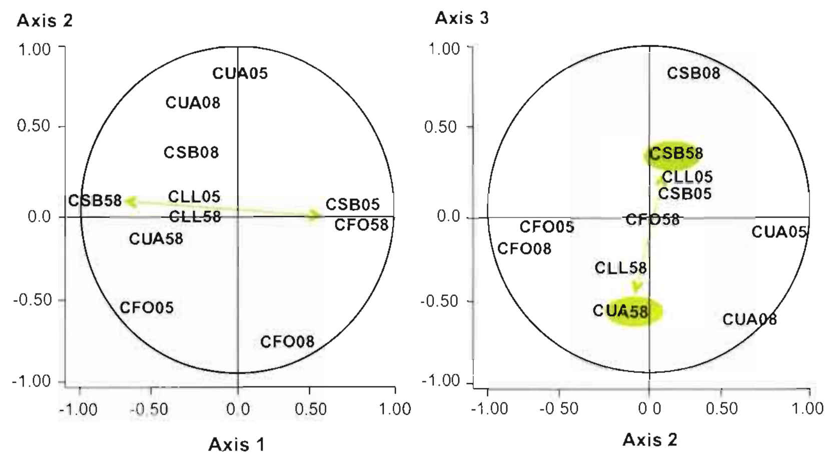
AREAVILL: village area (ha)

Area of land use classes in 1998 (ha):
LLR98 : paddyfield area
UAG98 : upland crop area
SHR98 : shrubland area
FO98 : forest area

Change in land use area between 1990 and 1998 (ha):
CLL08 : variation of paddyfield area
CUA08 : variation of upland crops area
CSB08 : variation of shrubland area
CFO08 : variation of forest area

The first two axes account for 47% of total variance, and are composed of the land-use variables. The first axis (28% of total variability) opposes villages whose forest cover increased from 1990-98 (variable CFO08) against villages whose shrubland increased (CSB08). Also on this axis, we find high 1998 paddyfield proportions (LLR98) associated with the former group of villages, and extensive hillside cultivation (UAG98) and shrubland (SHR98) in 1998 associated with the latter, supporting the arguments made in section 3.2 above. The second axis (19%) contrasts variations in forest area against variations in hillside cultivation area, revealing the inverse relationship between these variables.

Figure 10: *Relating land use changes to 1998 land use: axes 1 and 2 of a principal components analysis*



Variable names: change in land use area (ha)

between 1990 and 1995	**between 1995 and 1998**	**between 1990 and 1998**
CLL05: paddyfield area	CLL58: paddyfield area	CLL08: paddyfield area
CUA05: upland crop area	CUA58: upland area	CUA08: upland crop area
CSB05: shrubland area	CSB58: shrubland area	CSB08: shrubland area
CFO05: forest area	CFO58: forest area	CFO08: forest area

The first of the three axes deepens our analysis of the relationships among land uses in the studied periods. We can see very different land use evolution in the two studied periods, 1990-95 and 1995-98. In 1995, hillsides and forestlands were all allocated to individuals, whereas before they had been available to all in a free-access system. This change transformed local natural resource management (Castella et al., 2002b).

- The first three axes of the PCA together account for 70% of total variance. The first axis (31%) shows the inverse relationship between changes in forest cover (CFO58) and shrubland (CSB58) between 1995 and 1998, suggesting that shrublands were regrowing into taller forests. An association between forest cover expansion during the second period (CFO58) and shrubland expansion during the first period (CSB05) shows that forest regeneration followed a period of intensive clearing.
- The second axis (22%) demonstrates the opposition between upland crop expansion during 1990-95 (CUA05) and forest expansion during the same period (CFO05). This axis also shows a connection between changes in both upland crops and forests during 1990-98 (CFO08, CUA08), and changes during 1990-95 (CFO05, CUA05), demonstrating that most changes observed over the period 1990-98 actually happened during 1990-95, before the upland allocation that seemed to have a rapid impact on the diminution of upland crop areas.
- On the third axis (17%), we see upland crop expansion during 1990-95 (CUA05) in opposition to forest cover increases during the same period, suggesting that upland crops were developed at the expense of the forest during 1990-95 (CFO05) before the upland allocation, but at the expense of shrublands following the upland allocation, after 1995 (CSB58).

Figure 11: *Principal components analysis of changes in land use, 1990-95, 1995-98, 1990-98*

5. Determinants of land use changes

The next phase of our study was to bring the socioeconomic context into the picture, to explain the land-use changes described above.

Historically, the availability of natural resources has been a reason for the colonization of new areas by various ethnic groups (Mellac, 2000; Castella et al., 2002c). Areas where irrigated paddyfields could be built were settled by the *Tày*, whereas areas rich in forest were settled by the nomadic *Dao* and *H'mong*. This distinction between *Tày* and *Dao* villages in *Cho Don* remains clear today. Although ethnicity is no longer a determining factor of the goals of farmers, its historical role has helped determine farmers' access to resources today. In *Ngoc Phai* Commune of *Cho Don* District, Castella et al. (2002c) documented the way in which the past role of ethnicity, determining which families settled which areas, has shaped villages' present-day circumstances.

In addition to proximity to natural resources, the relative accessibility of an area also has a substantial impact on the implementation of land policy. Alther et al. (2002) demonstrated that accessible sites offer development opportunities unavailable to remote or isolated areas. In particular, accessible areas benefit from marketing channels for agricultural produce and access to development aid projects. Based on data about access to markets, health services, news sources, and the national electricity network, we calculated accessibility indicators for villages in *Cho Don* as shown in Figure 12. We then integrated these indicators with socioeconomic data from each village such as population, ethnicity proportions, poverty rates, and literacy rates. The statistical analyses resulting from this integration are shown in Figure 13.

The first PCA in Figure 13 relates landscape dynamics with variables that describe accessibility and ethnicity. On the first axis, the *Tày* (TAY) and *Kinh* (KINH) are associated with high paddyfield areas (LLR98), good accessibility (ACCESSIBILITY) and forest regeneration during 1990-98 (CFO08). On the other side of the axis are the *Dao* and *H'mong* groups (DAO-HMONG), who are associated with remoteness (REMOTENESS), high upland crop areas (UAG98), and large tracts of shrubland (SHR98). These villages (type III from Figure 4) have shown decreasing forest cover and increasing shrubland over the studied period (1990-2000).

It is also worth emphasizing the direct relationship between accessibility and the presence of irrigated paddyfields. The ancient arrival of the *Tày* and more recent arrival of the *Kinh* in the irrigated lowlands explain the relationships between the variables on the positive side of axis 1 in Figure 13 (Castella et al., 2002c). The allocation first of lowlands and then of uplands secured the right of the *Tày* to retain possession of the irrigated paddyfields, allowing them to concentrate their activities there. This reduced pressure on the hillsides, evidenced by the recent forest regeneration in *Tày* communities. Meanwhile, the *Dao* and *H'mong*, marginalized both by their remoteness and by the most-recent land policies, continue to engage in slash-and-burn cultivation despite knowing that it is only a short-term way to feed their households (Castella et al., 2002 and 2002c). Finally, some *Kinh*, dispossessed of the paddyfields they had farmed during the cooperative period, have developed non-agricultural activities by building upon their social networks, access to marketing channels, and the road system. Non-agricultural activities provide them with a substantial portion of their household income, and have enabled some of them to purchase paddyfields.

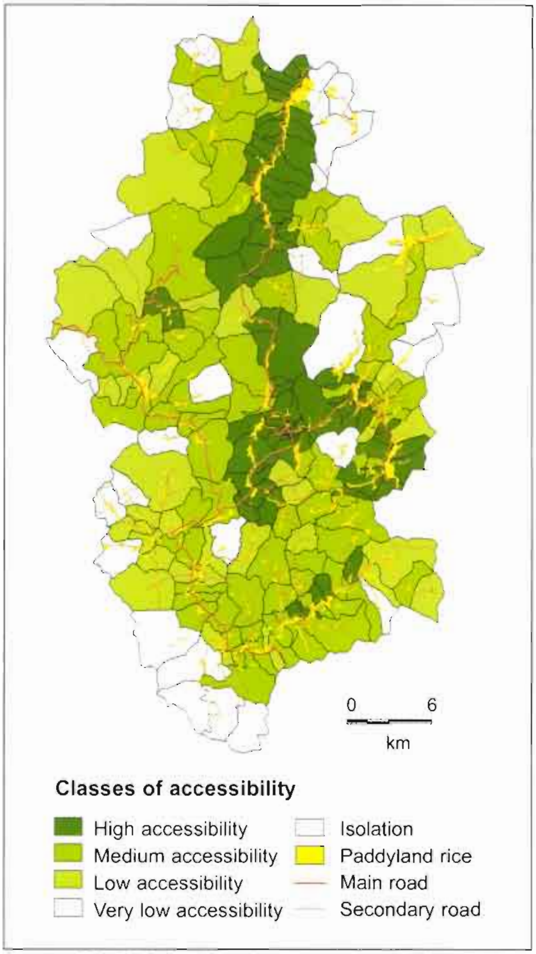
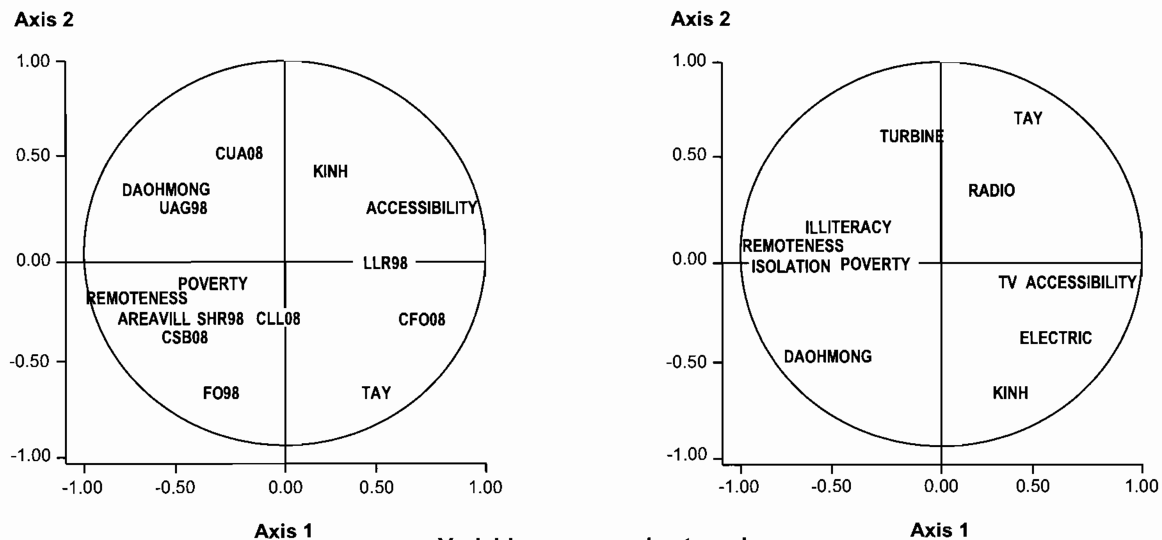


Figure 12: *Relationships between accessibility, road and irrigated ricefields*

N.B.: Accessibility indicator was calculated based on the quality of the transportation networks (roads).

The second axis in Figure 13 reveals the oppositions between the *Tày* and *Kinh* ethnicities. *Tày* villages (TAY) are associated with large forest areas (FO98) and forest regeneration (CFO08), whereas *Kinh* villages (KINH) are characterized by a temporary increase in upland cultivation (CUA08). From our monographic studies (Sadoulet et al., 2002; Castella et al., 2002b), we have learned that some *Kinh*, after losing possession of their paddyfields in 1990, turned to slash-and-burn cultivation from 1990-95.

The second PCA in Figure 13 shows that *Kinh* villages have the best access to the national electricity network (association of the variables KINH and ELECTRIC). Meanwhile, *Tày* villages (TAY) rely on microturbines (TURBINE), using the streams and rivers that irrigate their fields as a source of electricity where the national power network is unavailable. On the other side of the first axis are the



Variable names and categories

Area of land use in 1998

LLR98: area of paddyfield
UAG98: area of upland
SHR98: area of shrubland
FO98: area of forest

Accessibility

REMOTENESS: remoteness
ACCESSIBILITY: accessibility
ISOLATION: isolation

Change in land use area between 1990 and 1998

CLL08: variation of paddyfield area
CUA08: variation of upland crops area
CSB08: variation of shrubland area
CFO08: variation of forest area

Ethnicity

KINH: percentage of *Kinh* households
DAOHMONG: % of *Dao* and *Hmong* households
TAY: percentage of *Tày* households

Socio-economic

POVERTY: poverty rate
ILLITERACY: illiteracy rate
ELECTRIC: access to national electricity network
TURBINE: hydroelectric micro-turbine
TV: number of television sets
RADIO: number of radios

Other

AREAVILL: village area

Figure 13: *Principal component analysis combining the biophysical and socioeconomic characteristics of Cho Don villages*

marginalized shifting cultivators (DAOHMONG), characterized by remoteness, isolation, high poverty, and illiteracy.

These results support the hypothesis that there is a strong relationship between the biophysical and socioeconomic characteristics of the studied villages. The statistical results further support official extension approaches that associate each ethnic group with production strategies of various levels of sustainability. This ethnicity-based classification is valid today primarily because of the historical forces that affected how farmers gained access to natural resources. However, our monographic studies have shown that the *Dao*, for example, are not particularly attached to slash-and-burn cultivation, and are eager to purchase irrigated paddyfields when the opportunity presents itself (Castella et al., 2002c). Rather, they engage in slash-and-burn cultivation because their particular institutional and environmental setting does not offer them any other alternatives (Sadoulet et al., 2002). Specifically, they are constrained by their lack of irrigated paddyfields.

6. Conclusions

Our geographic approach consisted of examining and characterizing agro-ecological diversity at the district level and then at the village level. Through this approach, we showed that the present-day diversity among villages was dependent both on village structure (relative sizes of various landscape units) and on recent land-use changes. Knowledge gained in monographic studies contributed to this geographic understanding, allowing us to examine the interactions between landscape and natural resource management practices. The geographic and socioeconomic aspects of the survey converge at the village level, allowing us to explain district-level changes in land use in terms of local production strategies. We can now use what we have learned to generalize our understanding of complex agro-ecosystems to wider geographic areas.

In *Cho Don*, we observed deforestation from 1990-95 and then reforestation from 1995-98, demonstrating the positive effects of a 1995 land allocation policy. However, this over-generalized view masks substantial inter-village discrepancies. Type II villages (Figure 4), with small overall areas but large paddyfields, are highly accessible and populated by farmers of the *Tày* and *Kinh* ethnicities. In contrast, Type III villages are larger, based on forests and upland crops, and are populated by the *Dao* and the *H'mong* people. There remains a clear dichotomy between (i) low-accessibility villages populated by shifting cultivators and (ii) villages that are located along wide flat valleys, have good infrastructure and accessibility, and are populated by paddy-rice growers. Statistical analyses further demonstrated the main biophysical and socioeconomic elements that dichotomize these two types of villages and their recent evolution.

Although ethnicity was a major factor in explaining past landscape dynamics, it is already losing relevance as a helpful indicator. Today we can find farmers of all ethnicities engaged in all kinds of production strategies. As rural infrastructure and communications develop, particular groups will no longer be isolated and confined to particular production strategies. In addition, future population growth will reduce per capita paddyfield area. It is worthwhile to anticipate these transformations and to begin to develop new indicators that will help to characterize the future trajectories of each kind of village.

Whereas external factors, such as land allocation policy, are central to understanding previous village trajectories up to the *Doi moi* period, in the future we can expect internal village factors (e.g. population pressure, production strategies, resource management institutions) to structure land use dynamics. Villages are not equal in their potential for development, and it is important to recognize these inequalities. Development activities should be targeted with this recognition in mind, to assist the most marginalized of villages in transforming their production systems. Villages with economies based on shifting cultivation can be easily identified in our survey, based on their lack of irrigated paddyfields, low accessibility, *Dao/H'mong* populations, and recent forest deterioration. These criteria could be helpful in helping development programs target these most marginalized communities (Castella et al., 2002).

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