7th conference ASAE ("*Meeting the Challenges Facing Asian Agriculture and Agricultural Economics Toward a Sustainable*"), Hanoi, 13-16 October 2011. Accepted for oral presentation

Theme : Vietnamese Agriculture and Rural Development, Problems and Strategies

# Impact assessment of hydropower dam on erosion risk within a hilly agricultural area: example of the Ban Chat dam (Northern Vietnam)

Nguyen Van Thiet[1*]., Orange D[2]., Pham Van Cu[3]., Tran Duc Toan[4]., Hoffmann F[5]., Pomel S[5]., Laffly D[6].

1*: Institute of Agricultural Environment (IAE), VAAS, Hanoi; nvthietiae@yahoo.com
2: UMR211-BIOEMCO, Institut de Recherche pour le Développement (IRD) - France
3 : Vietnam National University (VNU), Hanoi
4 : Soils and Fertilizers Research Institute (SFRI), VAAS, Hanoi
5: University of Bordeaux 3 - France
6: UMR GEODE, University of Toulouse Le Mirail - France

## Abstract

In Vietnam, intensification and densification of sloping lands led to impass environmental programs despite the technical support policies of conservation agriculture. On the one hand, these programs were intended to improve or replace the systems supposedly unsuitable for traditional farming communities. On the other hand, many programs have promoted reforestation for soil protection and upstream watershed management. But the success of these initiatives was never expected that, both as regards the improvement of living conditions as environmental benefits. Our study dealt with the impacts of the building of 3 major hydropower dams (Son La, Huoi Quang and Ban Chat) regarding the land-use change and the environmental sustainability based on the erosion risk within the example of the Ban Chat dam in Lai Chau Provinces. In this region of small mountains, the annual crops, particularly maize and cassava, showed significant erosion risk that can exceed 30 t/ha/yr. But the surface area used for agricultural lands is often very low, below 20%. Then the regional erosion risk at the dam watershed level seems quite low, generally around 5 t/ha/yr. However this study underlines the erosion increases of 20% over the last ten years in Ban Chat watershed, with a maximum land-use change early before the dam building. An acceleration of the disappearance of the fallow zones occupied by shrubs (decrease of 17 800 hectares, i.e. -18%) is observed to be replaced by tea plantations and planted forest due to the opening access to economic market, driven by the hydropower planning. These trends suggest increasing fears of severe agricultural pressure on slopes, driving economic and environmental problems. At last, we suggest some pathways to elaborate an appropriate land-use assessment system for project monitoring and improved land planning before the dam construction, to be sure to identify project's opportunities for legitimacy and relevancy.

Key words : Hydropower, Erosion, Agricultural policy, Rural development, Land use change

## 1. Introduction

While the era of dam building in the last 90's was largely over under the large controverse driven by the World Commissions on Dams (WCD, 2000), globally dams are still being proposed and constructed, especially in Southeast Asia (Duflo, Pande, 2007). Moreover it is nowadays assumed that hydropower dams could represent a positive alternative of sustainable development (Brown et al., 2008; Bohlen, Lewis, 2009). Then it is an absolute requirement to improve our capacity to prevent the socio-economic and environmental trends of hydropower dams, notably in regards of a predictable time span of the dams for a well-being management associated with environmental sustainability and economic rentability (Sternberg, 2010). Moerover, the hydropower projects require prolonged planning and construction periods before the effective use of the dams. We propose in this paper to tackle the erosion risk of hydropower dam before and during its construction.

Vietnam can be viewed as both a hydropwer developer and importer of electricity. Potential hydropower electricity is estimated to be approximately 20,600 MW of which 20% (4,200 MW) has been developed to date (Bach Tan Sinh, 2009). Projections suggest that about 13,000 MW of new hydropower dams would be added to the grid system up to 2020 that would represent approximately 65% of Viet Nam's economic hydropower potential (Dao, 2010). In average, the electricity demand is growing at between 13-15% per annum associated with increasing demand from the household sector, rising industrial sector and export growth. It is anticipated that this growth will continue into the foreseeable future as Vietnam achieves its goals in becoming an industrialized economy in the next 20 years (King et al, 2007). In Vietnam, currently there are more than 50 hydropower dams in operation. They are predominantly located in the Central and Northern regions with the Da, Sesan and Dongnai rivers.

But also in other countries in the region, hydropower is booming. Companies that have their constituents in Thailand, Vietnam, China, Russia and Malaysia are increasingly joining tradition investors such as the World Bank and the Asian Development Bank. This diversity has been accompanied by new thinking in dam operation, with many investors keen both to work with upland land users to increase the dam profitability and to be, and be seen as, responsible partners in development. The question is how to develop the mechanisms to turn the potential interest and revenue into positive environmental and economic impact?

On the other hand, the uplands of Southeast Asia comprise approximately 50 million hectares of land on which over 100 million people are directly dependent for their livelihoods. These uplands regions include flat to steeply sloping areas that are extremely vulnerable to accelerated degradation when disturbed or converted to agricultural use (Maglinao, Leslie, 2001; Tran Duc Toan et al., 2003; Maglinao et al., 2004; Valentin et al., 2008). In the last two decades, Vietnam has experienced throughout its territory tremendous changes related to land reform and economic growth that ensued (Le Trong Cuc, Rambo 2001; Castella, Dang Dinh Quang, 2002; Tran Duc Vien, 2003; Castella et al., 2005). However, the improvement was not uniform (Tran Duc Vien, Rambo, 2001; Clement et al., 2009). Economic development in mountainous area of North Vietnam was slower, still leaving areas where poverty is still present (Bach et al., 2011). Upland areas tend to be remote with poor access to markets and are often inhabited by ethnic minorities who are socially and politically disadvantaged (Lestrelin, Giordano, 2006; Orange et al., 2008; Clement et al., 2009). High population pressure and low agricultural productivity in the uplands pose real challenges for designing development strategies that not only alleviate poverty and support economic development with urbanization but also protect a sustainable environment (Orange, Noble, 2010).

Moreover, it is worth underlining land degradation associated with upland systems is widely recognized as a one of the most important issues for improving the human and natural environment in Southeast Asian regions. Soil erosion has major negative economic impacts both on- and off-site (UNEP, 1991; Lal, 1998; Roose, 2004; Valentin et al., 2008). These include declining agricultural productivity, a reduction in storage capacity and delivery facilities of dams and reservoirs downstream, increasing pollution of drinking water, damage to irrigation infrastructures, and a threat to aquatic ecosystems as well as human health (e.g. Scherr, 1999; Wani et al., 2001; Tognetty, Johnson, 2008). As an example of the offsite costs of upland degradation, the Vietnamese hydropower authority EVN declared in 2002 that the span-life of the large Hoa Binh dam built in the 1980's had been halved due to sedimentation from uplands.

Each year, unproductive erosion makes 20 million hectares worldwide (UNEP, 1991). Quantify the impact of agricultural practices on soil erosion is essential not only for technicians to advise farmers on conservation practices to more sustainable use of their heritage, but also for policy makers who must provide appropriate policy management natural resources and soil conservation. If all operators can empirically estimate the scale of the decade the decline in yields, mainly attributed to erosion, very few have a clear idea of the impact of their farming practices on crop yields. In Southeast Asia, the erosion is mainly explained by both the lack of vegetation cover and the intensification of cropping systems under the influence of the economic market (Valentin et al., 2008). Based on the decennial research studies of the MSEC programme (Maglinao et al., 2004), it has been demonstrated that the best indicator of soil loss is the percentage of corn crop, and annual crops in general, but not the percentage of forest or vegetation cover. Finally, farmers strategies are primarily opportunistic, highly linked to market forces (Clement et al., 2008; Orange, Noble, 2010).

This paper seeks to understand the previous impact of hydropower development projects on land-use change raising erosion processes. The experimental watershed of this study lies in the south-eastern of Lai Chau Province (in Than Uyen District and Tan Uyen District) inside the geographic triangle formed by the three large hydropower dams of Son La, Huoi Quang and Ban Chat. In this area, the agricultural products are the main income. Data and information for this paper are based on fieldworks driven by the authors during these last two years. The first part of the paper outlines the land-use changes from 2000 to 2009 by a diachronic analysis at district level. The second part of the paper traces the behavior of the farmers based on open-ended and questionnaire-based interviews with affected people. At last, the third section speaks to the implication for the erosion firstly based on the dam planning period and secondly according some economic scenarios after the flooded period of Ban Chat dam.

## 2. Materials and methods

### *2.1. Son La cascade dams*

Early 2000's, the "National Plan for Hydropower System" has studied a cascade of large hydropower dams on the Nam Mu River in coordination with that of the Da River so as to establish a complete system which can make use of the hydropower potential of the Da river system. Moreover this National Plan underlines a common knowledge that the construction and operation of a multi-purpose hydropower plant will inevitably cause environmental and socio-economic impacts, positive and negative ones. In 2001, construction of the Son La hydropower project on the Da river (about 250 km from the Hoa Binh dam) was formally approved by the National Assembly of the Socialist Republic of Vietnam (Decision No44/2001-QH10). It was a 100% state-funded and managed project. In 2004, the Hydropower Project Management Unit No.1 (under direct management of EVN) prepared the EIA report (Environmental Impact Assessment) for two additive large dams: the Huoi Quang Hydropower Project and the Ban Chat Hydropower Project, both on the Nam Mu River in almost 50 km above the Son La Hydropower dam. These three dams are more than 215 m tall for Son La and 100 m tall for the two others, caused the displacement of about one hundred thousand people across three Provinces: Son La, Lai Chau and Dien Bien, with more than 80% belonged to the Thái ethnic group. The three projects flooded around 30,000 hectares, of which more than one third hectares was agricultural land including rice paddies, gardens and fishponds (PIDC No. 1, 1999). Among the displaced households, more than 85% engaged in farming, depending entirely on arable land (VUSTA, 2006). Thus, as with many of the existing dams in Vietnam, Laos or China, the affected people consisted mostly of ethnic minority groups. One of the major concerns of both local governments and environmental groups continues to be a shortage of land for resettling the tens of thousands of displaced people (Brown et al., 2008; Bach Tan Sinh, 2009; Dao, 2010). Finally, the whole plan should be completed and put into full operation in 2020.

### *2.2. Socio-economic and social data mining*

This study was built on the analysis-diagnostic of agrarian systems methodology (Dumont et al., 1999), adapted to the context which didn't allow for undertaking a comprehensive study (Carro, 2010). The main constraints at the time of study were as follows: (i) no or virtually no previous knowledge of agrarian systems in the studied watershed; (ii) a willingness to build the project on a participatory basis which required to identify and meet with a great number of stakeholders at the village, commune and district levels; (iii) the environmental focus of the project which required to consider land-use at the watershed level rather than at farm-level; (iv) the early stage of the project which required to allocate considerable time for establishing contact and build confidence with stakeholders, which, although it was a necessary step for ensuring project's future activities, further limited the work that could possibly be achieved on the field. In that context, we decided to exclude a number of aspects which would have required to undertake too much time-consuming activities, and reduced the diagnosis' objectives to the following: (i) identifying stakeholders who have, or may have in the future, an impact on the watershed's land-use and understanding their interests and concerns; (ii) assessing the land-use and land-use change in the watershed; (iii) identifying the main crops agro-ecological localisation and associated cropping systems; (iv) establishing a preliminary typology of the farming systems in the watershed's hot-spot based on their technical and financial functioning; (v) identifying the main agricultural and rural constraints in the watershed.

### *2.3. Study area : Tan Uyen and Than Uyen Districts, Nam Can Commune*

For this study, we worked specifically in the watershed impacted by the Ban Chat dam, the most northward of the Son La cascade dams. This watershed is more or less matching with the addition of Tan Uyen and Than Uyen Districts from Lai Chau Province (fig. 1). In a second step, we have focused our research effort at commune level with Nam Can Commune. The total surface of the commune is about 13 418 ha. The landscape is characterized by a moun tainous relief featuring a steep-sided hydrological network shaped in two main valleys: the narrow valley of the Nam Mu River, running North-South in the commune (Figure2: arrow 1), and the larger valley formed by two of its tributaries the Hua Can and Hua Puong streams, oriented Northwest-Southeast (Figure 2: arrow 2).

### *2.4. Environmental data*

The land-use change in Tan Uyen and Than Uyen Districts (with a total area of 170,000 ha) for the Ban Chat watershed were determined from the remote sensing data analysis of three Landsat images of the study area for three dates: October 2000, October 2004 and October 2009. All data including satellite images, topographical maps, geological maps and land use maps were geo-referenced and resampled in the same UTM coordinate system at 20x20 meters spatial resolution.

- Vegetation assessment: In order to the land-use map, a vegetation assessment was carried out in the field to define the different land-use types, taking into account the inherent limitation of remote sensing data sources and referring to other research in the region.
- Land use changes analysis: The results from interpreted satellite imagery and the classified digital images were compared to calculate changes of land-use in each period.
- Calculation of the soil erosion risk: the erosion calculation is based on a relation between vegetation cover and land-use measured during two field trips in contrasted season to calculate a soil loss risk as following (Nguyen Van Thiet et al., 2008):

$$\mathbf{S_R = D_b \times COV \times P_E}$$

with $\mathbf{S_R}$**:** soil loss risk (in t/ha/an); $\mathbf{D_b}$**:** soil bulk density; **COV:** % vegetation cover; $\mathbf{P_E}$**:** potential erosion which represents an annual soil loss in mm.

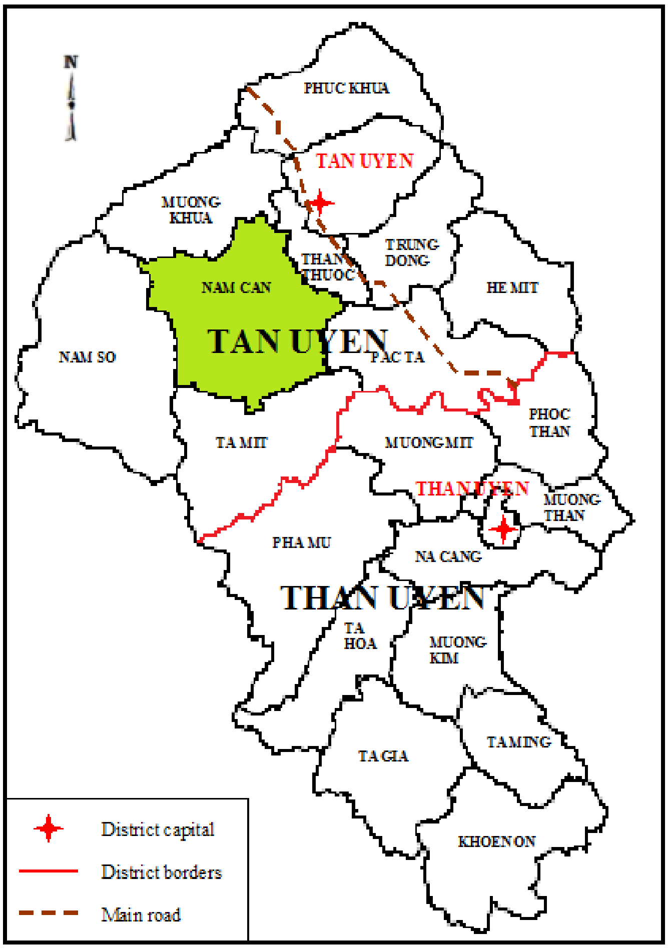


**Figure 1:** Location of Nam Can Commune (in green color) in Tan Uyen district. Source: adapted from Tan Uyen Natural Resource Management Desk's land-use map, 2010.

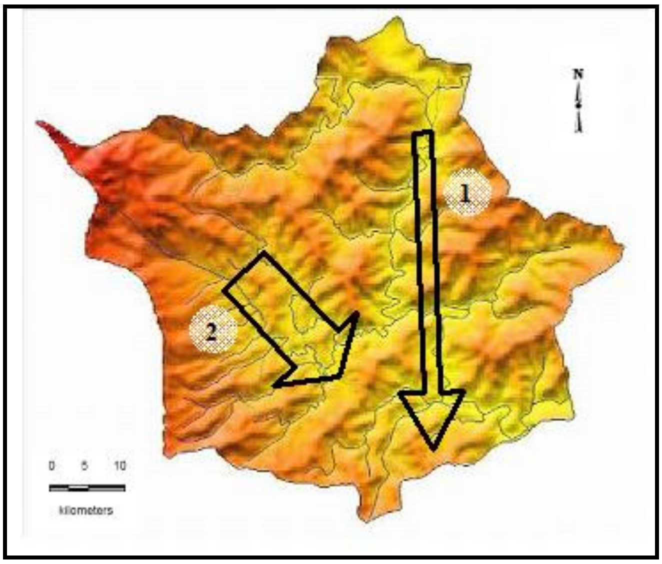


**Figure 2:** Nam Can watershed featuring the hydrological network in blue and the two main valleys: arrow 1) the Nam Mu River Valley; arrow 2) the Hua Can and Hua Puong streams' valley.
Source: this study, 2010.

## 3. Results

### *3.1. Diachronic study of the land-use change at the district level*

As listed in the Table 1, eight main land-use categories can be defined in this area. The shrubs cover around 50% of the surface area, the primary and secondary forest almost 20%, the flat lands less than 10% and the annual crops on slope around 10%.

The diachronic study over the last 10 years, from 2000 to 2009, underlines the increase of surface of tea plantation only from 2004 and of the planted forest quite regularly from 2000 (Fig. 3). This dissemination is associated with decrease of shrubs mainly and of few flat lands. The shrubs represented 59% of the watershed in 2000 and reduced to 43% and 48% in 2004 and 2009 respectievly.

The area of natural forest has not changed between 2000 and 2004. These figures indicate that forestry policy of the Vietnamese government has strongly protected the forest environment in Lai Chau Province. One reason is that the natural forest in the watershed belongs to the National Park of Hoang Lien Son. Second, policy to support food for participants in the protection of forests and shrub land conversion in rice terraces in the area of fallow land (10 million VND/ha) which is the goal to improve productivity rice for food security at the family level, which decreased deforestation phenomenon, also participated in the protection of the forest.

Finally the annual crops on slope are still widespread and have been developed mainly between 2000 and 2004, with an increase of 2,104 ha (around 10%) in 5 years. These surfaces are won on the fallow areas, incorporated in the shrub category in the Table 1. From 2004, the surfaces of annual crops on slope are stable, but netherless remain important with around 11% of the total watershed surface. The annual crop is mainly Maize culture, driving an important potential risk of soil erosion.

***Table1:*** *Surface cover (expressed in ha) of land-use categories in Tan Uyen and Than Uyen Districts, from 2000 to 2009, calculated from Landsat imagery. Source: this study, 2010.*

| **Land-use category** | **2000** | **2004** | **2009** |
|---|---|---|---|
| Annual crops on slopes | 15,880 | 17,980 | 17,980 |
| Planted forest | 0 | 6,050 | 12,640 |
| Tea plantation | 5,090 | 9,400 | 10,160 |
| Shrubs | 99,920 | 89,980 | 82,110 |
| Secondary forest | 5,720 | 5,720 | 5,720 |
| Primary forest | 27,690 | 27,690 | 27,690 |
| Flat lands | 15,100 | 12,580 | 12,500 |
| Urbanization | 600 | 600 | 1,200 |
| **Total** | **170,000** | **170,000** | **170000** |

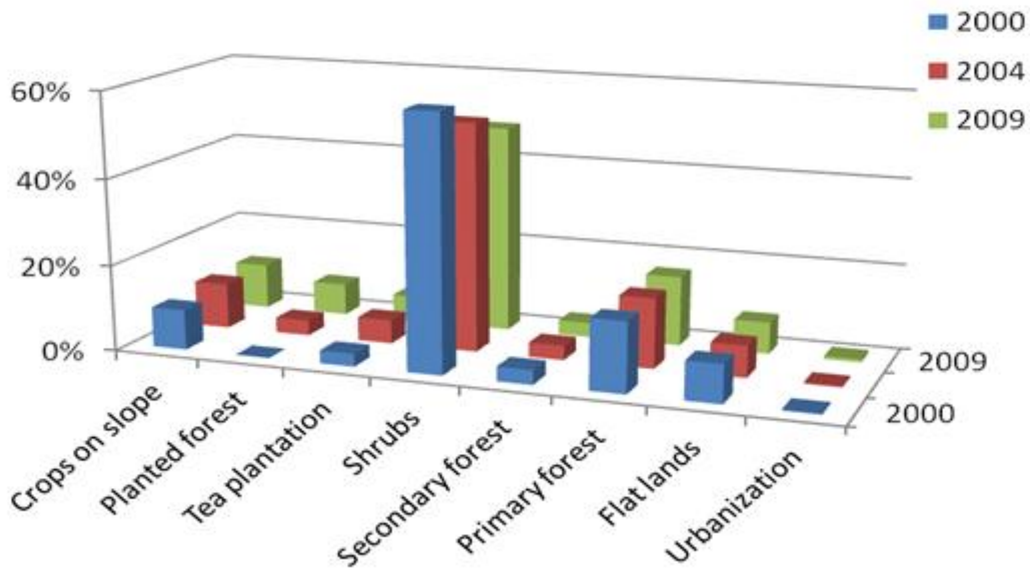


**Figure 3:** Land-use change over 10 years in Than Uyen and Tan Uyen Districts.
Source: this study, 2010

The land-use change has been more important from 2004 to 2009 than before (fig. 4). It seems to have been accelerated. In fact, the agricultural policy has been largely changed due to the beginning in 2006 of the two constructions of the hydropower dams (Ban Chat and Huoi Quang). Moreover two new districts (Tan Uyen and Than Uyen) have been created in order to divide the former Than Uyen District. This policy aims to accompany a rapid economic development in the region whished in association with the Son La cascade dams. Between 2004 and 2009, two major land-use changes raised:

- the urbanization to establish the new administrative center of Tan Uyen district,
- the great expansion of planted forest by *Acacia Mangium* (from zero ha in 2000 to 6,000 ha in 2004 and more than 12,000 ha in 2009 (fig. 4).

At last, it is worth to underlining that the tea plantation has been expanded from 2000 to 2004 and not too much after. Moerover this expansion has been done at the expense of the shrubs, which is driving again an important risk of soil losses.

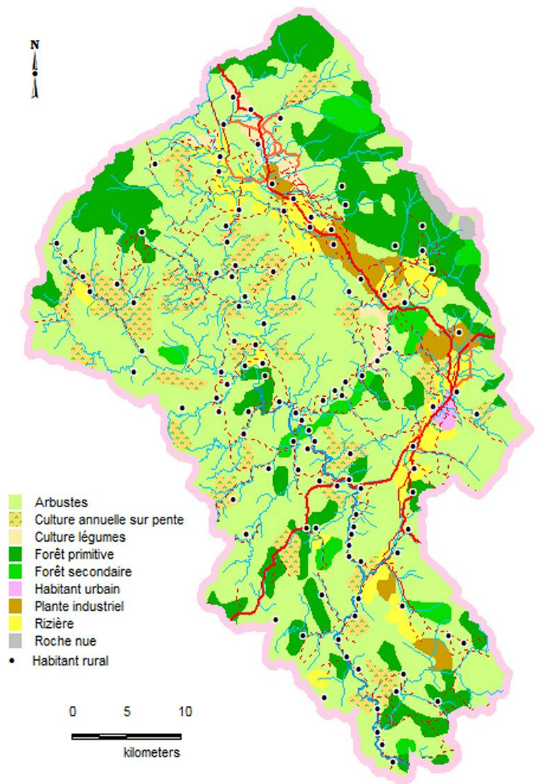


**Fig. 4a**

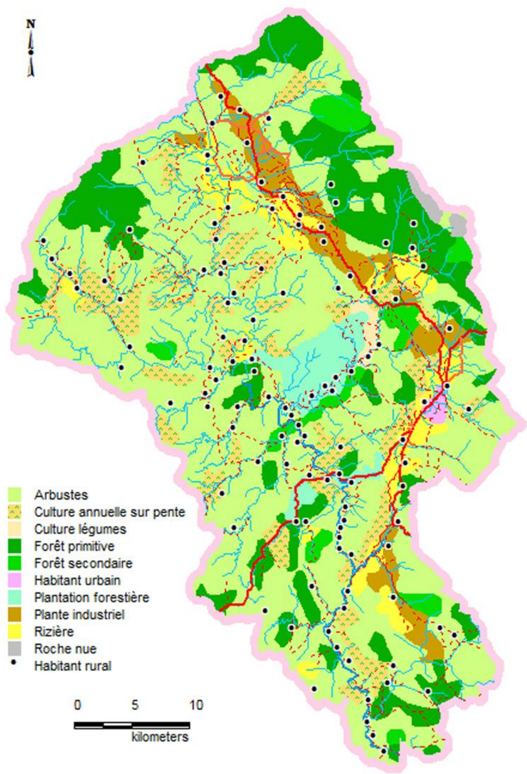


**Fig. 4b**

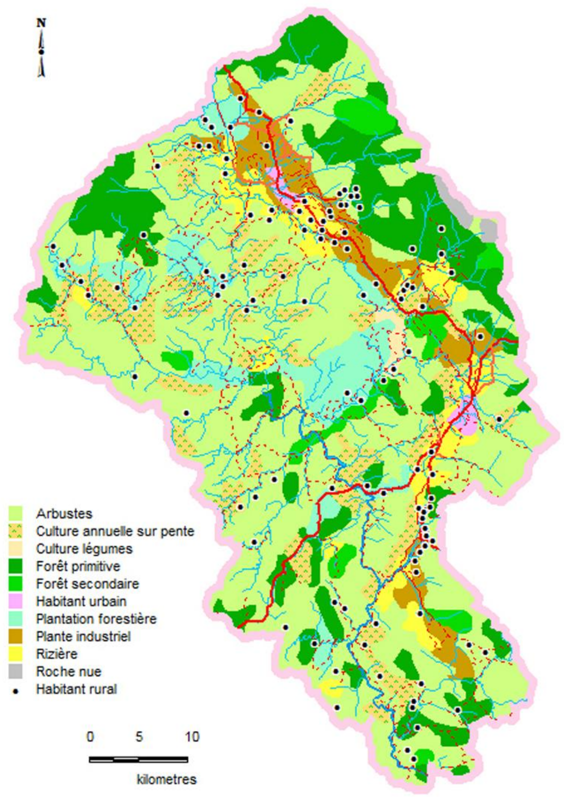


**Fig. 4c**

**Figure 4:** Land-use map f the Tan Uyen and Than Uyen Districts, reputed to be the Ban Chat Dam watershed, from Landsat analysis, between 2000 (fig. 4a), 2004 (fig. 4b) and 2009 (fig. 4c).
Source: this study, 2010.

### 3.2. Farmers' needs and agricultural surfaces in Nam Can Commune

*Village-level governance structures*

Beyond cultural, political and historical factors, community organization in Nam Can commune has been shaped by a long-lasting relative reclusion from the outside world and a tradition of subsistence farming. In this context, solidarity has played a central role in sustaining each others livelihood while facing social and agricultural accidents. Although solidarity expresses itself for a large extent within the enlarged family circle -which often goes beyond the village-community boundaries- at the village level it has resulted in the build up of strong community organization. More specifically, community organization aimed to provide, amongst others, the following services: (i) provide a decision-making and conflict resolution structure under the form of the village council; (ii) assist households facing agricultural or familial difficulties through the provision of a village fund or other solidarity mechanisms; and (iii) provide a legal framework regarding resource sharing, labour exchange and households' participation in tasks that benefit the community as a whole -such as irrigation network maintenance and repairing.

With the assimilation of Tai and Kho Mu ethnic groups, this social organization was progressively overlapped by the Kinh governance model, but it didn't collpase: village councils remain the decisional structure, traditional rules define to a large extent individuals' duties and rights regarding the community and in many cases village funds are still running. However the hybridizing with Kinh's governance model had few worth-to-note consequences.

First it has singularly modified village chiefs' roles and status who globally won in executive power while losing on their legislative power. From representatives selected by and for the community to make decision according to traditional laws, they switched into functionaries –although still designated by the community they have to be recognized by the commune administration- committed with ensuring Vietnamese law enforcement in their community. Also, they issued additional responsibilities amongst which we can cite: (i) providing the commune with statistics related to all matters; (ii) transmit information from the district/commune to the village-level, and complains and demands from the village to the commune/district-levels; and (iii) supervising the implementation of all activities decided at the commune/district levels. Thus village chiefs' assignment consumes considerable time and involves numerous journeys through the commune to attend regular meetings (usually held once a week) in Phieng Bay. They are designated every five years by the village community members through a –seemingly quite democratic-like- participatory process.

Secondly, communities had to re-organize themselves according to the Vietnamese nation-wide associative scheme in order to benefit government supports which includes the following structures: (i) Farmers association; (ii) Women association; (iii) Youths association; (iv) Elders association; and (v) Veterans association. Each association is constituted of members, a head of association and usually a vice-head designated by these latter. Membership usually involves a small participation which can be monetary or in nature. Half of the fund raised is transferred to the commune-level association, the other half serving to implement the village association activities, support the meetings or is kept aside for different purpose.

In parallel to these structures, the communist party –usually constituted of one secretary, one vice-secretary and a handful of members in each village- is in charge of providing guidelines for good governance related to all matters -accordingly with upstream recommendations- and provides advice to villagers on how to stay/become an integrated member of the community. Its representatives works in close collaboration with decision-makers and village chiefs are often whether members or secretary of the communist party themselves.

*Land-use in Nam Can Commune*

The Nam Can Commune occupied 13,418 ha in Tan Uyen District. According to Tan Uyen's Forestry Desk, the forest cover was approximately 12% of the commune's territory (1,600 ha) in 2009, with 30% for planted forest (around 480 ha).The agricultural lands represent 730 ha, i.e. only 5.5% of the Commune's area. As we didn't dispose of the initial dataset which was used to build the map, to evaluate the respective importance of each crop within these 5.5% of agricultural land, we can only refer to the information provided by Nam Can People's Committee or directly by farmers and Chiefs of village. Thus the dataset produced should be interpreted very cautiously and we observed significant differences in the surfaces declared –even for notarized land in some cases- between 2009 and 2010 in which many inconsistencies are found. Furthermore, the complexity of cultivation systems makes a misleading source of information for assessing surfaces as it will be developed below.

Paddy fields occupy the largest part of the commune's agricultural land (35%), followed closely by cassava (28%) and rainfed rice (25%). Dry crops altogether represent only 11% of agricultural land, with maize coming in first position (9%) and a low percentage of soybean (2%) and peanuts (< 1%). However these figures give a fake idea of the occupation of land by agriculture because they are built on surface annually cropped and not on surface occupied. First, due to the practices associated with rainfed rice -and cassava to a lesser extent- cultivation in the area, the surface actually used to crop rainfed rice and cassava are under-estimated. Indeed rainfed rice cultivation is characterized by cultivation/fallow cycles, in which one or two years of cassava is incorporated in some cases after three years of rice. Duration of each phase of cultivation cycle depends on the agronomical potential of the slope-land exploited and the population pressure (e.g. the area available per household).

Secondly, when cassava is cropped as a monoculture on slopes above villages or on flatland aside the village, two cropping systems can be observed: (i) cassava is planted with a high density and fields are left in fallow for a year every three years; or (ii) cassava is planted with a lower density and doesn't require a fallow to restore soil fertility. In case number (i), farmers usually declare the area they crop and not the area left in fallow, thus under-estimating again the surface allocated for cassava.

Also, maize can be cropped under various systems: as a paddy field counter-season crop, as a monoculture or associated with soybean on river shores, as a monoculture or associated with cassava on flat-land, as a monoculture on gentle slopes. The percentages given don't take into account surfaces overlaps between paddy rice and maize in the case of paddy field cultivation, between soybean and maize in the case of river shores, and between cassava and maize in the case of flat-land. This result in an over-estimate of maize surface that is difficult to correct due to a lack of information on the relative importance of each cropping system.

Lastly, soybean and peanuts are always inserted within other crops cycles (paddy rice, maize or vegetable in the garden) or associated to other crops (maize or vegetable in the garden). Thus the surface they occupy shouldn't be taken into account here to avoid double-counting.

*Inadequation between agricultural surfaces declared and land-use needs*

As seen in the section above, agriculture and forestry is estimated to occupy a relatively low percentage of the commune's area (17% altogether). On Tan Uyen Agricultural Desk's map of land-use, where only paddy fields, dry crops fields and forest plots are displayed, the 83% of area remaining are represented as "unused mountainous land" or "unused flatland", areas reputed to be cover by shrubs. Although TUAD's staff declared that they knew those areas were actually used for rainfed rice cultivation, it is not represented because of the technical difficulty to define fields' positions along the whole cycle of cultivation. Then this representation of agricultural surfaces gives a totally biased idea of the actual land-use occupation in the commune.

Indeed, the village borders represented on the land-use map show that most of commune's surface is actually considered as "belonging" to villages, and thus the total surface each village dispose is in average 17 times larger than the agricultural surface declared. This can be explained by the steep-sidedness of the study zone relief that considerably reduces the surface exploitable: according to farmers only 10 to 30% of land is crop-able, depending on zones. Total surface available for each village and per inhabitant, calculated based on the land-use map using rough geometrical constructions, is presented in the Table 2.

***Table 2:*** *Total surface available per village and per inhabitant in Nam Can Commune (surfaces calculated after the installation of Quyet Thien Forestry Company). Source: this study, 2010.*

| | Phieng Ang | Phieng Bay | Phieng Luc | Phieng Ly | Phieng Tong | Bang Mai | Na Phat | Hua Can | Hua Puong | Total/Mean for the commune |
|---|---|---|---|---|---|---|---|---|---|---|
| Total surface (ha) | 724 | 481 | 220 | 638 | 172 | 851 | 2,659 | 1,557 | 1,428 | 8,731 |
| Surface per inhabitant (ha/inhabitant) | 4.6 | 1.9 | 2.4 | 14.2 | 1.4 | 5.7 | 4.9 | 7.6 | 4.1 | 4.5 |

The surface available per inhabitant varies considerably from a village to another: from 1.4 ha/inhabitant in Phieng Tong to 14.2 ha/inhabitant in Phieng Ly (Table 2, Fig. 5). In order to explain this variability, correlation coefficients with paddy field surface and rainfed rice surface were calculated. The result is that villages’ surface seems to be primarily correlated to the importance of rainfed rice cultivation (Fig. 6): the largest villages have the largest rainfed rice surfaces.

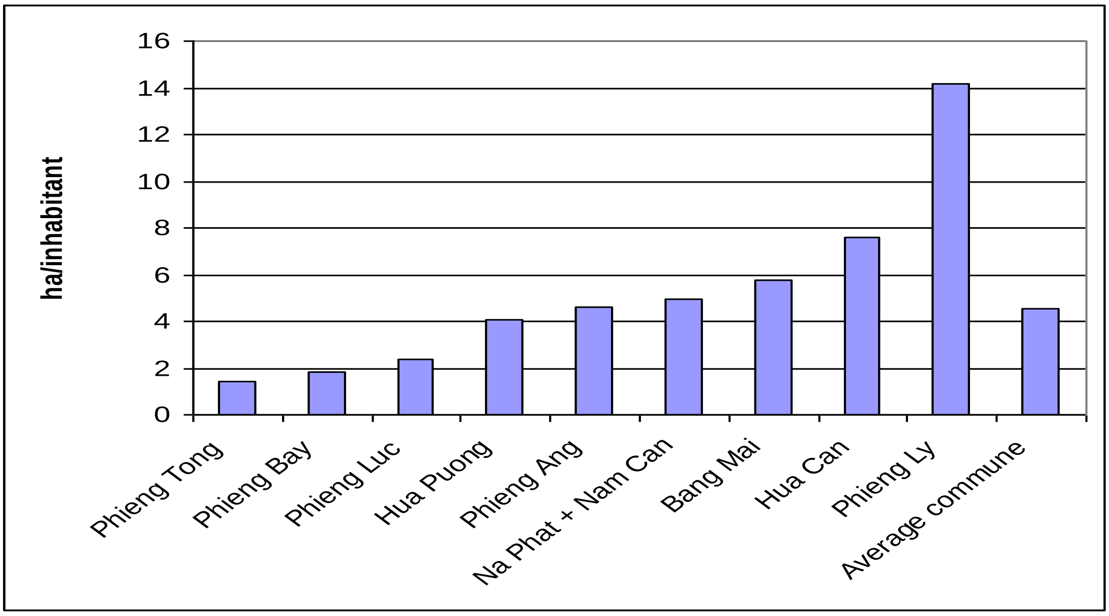


**Figure 5** : Surface available per inhabitant. Source: this study, 2010

From an agronomical point of view, this result is not surprising, rainfed rice being the most land-consuming crop amongst all observed. Implications in term of planning are greater. Indeed, it signifies that village borders established by farmers correspond to the area they actually need and use on a regular basis, even though large parts aren’t exploited and that some parts can be left in fallow for several years giving the illusion of abandoned land. Furthermore those marginal zones are also generally used as pastures for at least a part of the year, which is neither taken into account by TUAD. This automatically leads to improper planning as soon as these large areas of “unused mountainous land” or “unused flatland” are at stake. The case of Quyet Thien Forest Exploitation Company is a concrete example of the issue highlighted above: land was attributed to the company regardless of the use by local farmers were making of it, resulting in the impossibility to crop rainfed rice and a restricted access to pastures for them latter.

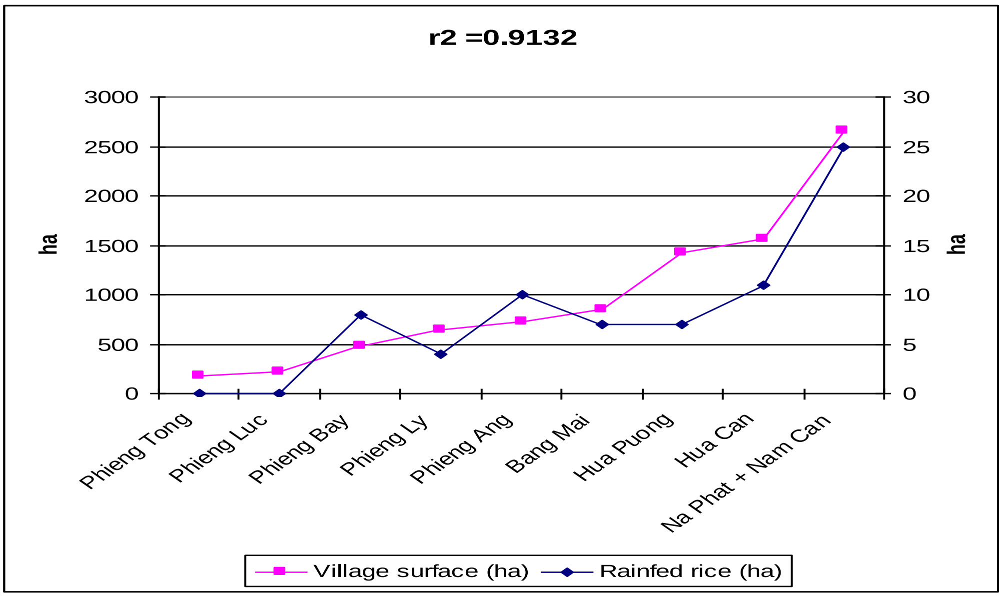


**Figure 6 :** Correlation between village surface and upland rice cultivation. Source: this study, 2010.

## 4. Discussion on impacts of the dam project within the Ban Chat watershed

### *4.1. Direct dam impacts: consequences of the flooding*

The Table 3 summarizes the main impacts of the dam on the watershed agriculture and their repartition in space and time:

**Table 3:** Current direct impacts of hydropower dam set up on agricultural areas

| Effect of the dam | Impact on the agricultural watershed | Impact zone | Impact timeline |
|---|---|---|---|
| 1/ flooding of agricultural land in valley bottoms on the Nam Mu River | ↓ S[valley bottom] /household | Nam Mu River valley | Immediate |
| 2/ flooding of settlements => population displacements => increased demographic pressure on the resettlement zones | ↓ S[total]/household | | |
| 3/ splitting of land by water | ↓ land availability | Nam Mu River valley enlarged | |
| 4/ change in micro-climatic patterns and especially an expected increase in rainfalls | Unknown | Whole watershed | Delayed |
| 5/ landslides and crumbling potentially affecting slopes on river sides, difficult to forecast | Potential ↓ S[valley bottom – slopes] /household | | |

In the Ban Chat watershed, the flooding concerns primarily the population living in the Eastern zone because it is concentrated in the Nam Mu river valley bottom (Fig. 7). It will have two immediate effects: (i) the loss of settlement requiring the displacement of households; (ii) the loss of the lowest agricultural land. Regarding this latter effect, only the lowest land is threatened, therefore the flooding will impact primarily paddy rice and dry crops cultivation, cassava in the southern most parts of the Nam Mu river valley. Our estimation evaluated the lost of 3,960 ha in flooded area, which represents 32% of flatlands areas and only 2% of the whole watershed.

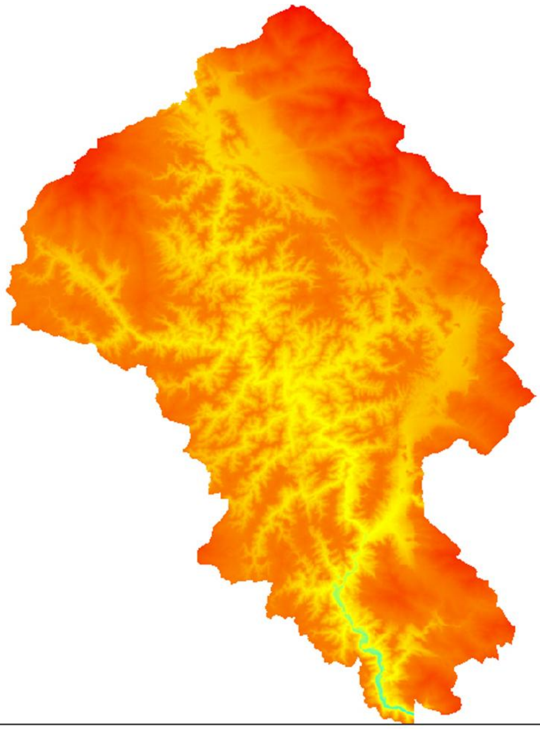

**Figure 7a:** Water level before building hydroelectric dam. Source: this study, 2010.

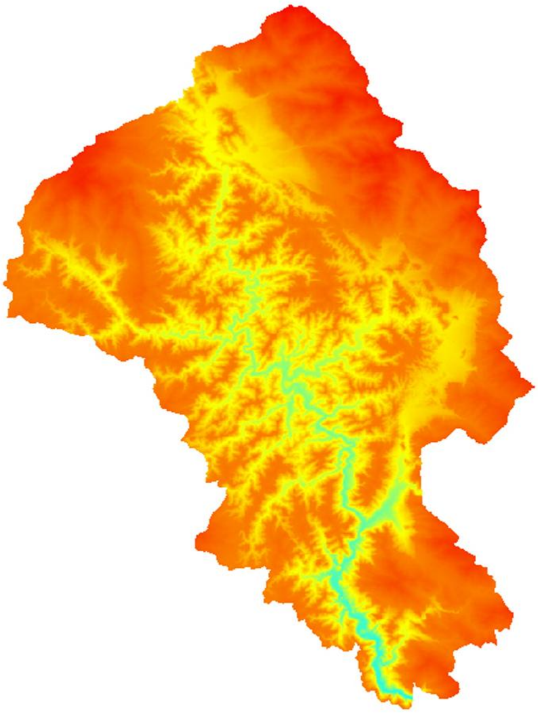

**Figure 7b:** Water level after building hydroelectric dam. Source: this study, 2010.

A compensation fund was created at the province level to compensate farmers' losses of land and settlements. In the commune a first commission of experts visited in early 2010 villages to be re-settled for estimating the losses. It is not clear whether non-notarized land will be compensated or not. According to village chiefs and Resettlement Committee of Than Uyen district (RCT), it will be taken into account. However, in the official document describing the compensation plan it is clearly said that only notarized land is eligible for compensation. Also, the procedure used for estimating land losses could result in inequities depending on farmers' position in the balance of power at the village level. Indeed, as for now the commission of experts worked mainly with village chiefs, rather than directly with farmers.

Official data on the total agricultural area expected to be flooded were not available for diffusion at the time of the study.

### *4.2. Impact of the dam before construction*

*Indirect impacts: consequences of population displacements*

As shown on the Figure 8, the resettlement plan will result in the concentration of a third of the watershed population at the very North-East of the commune, around Phieng Luc village. As seen in Table 2, the surface available per inhabitant in Phieng Luc is already one of the smallest in the commune. The re-settlement plan is expected to multiply Phieng Luc's density of population by a factor 4.5 to reach 185 inhabitants per $km^2$, which is nine times higher than the commune's average (around 20 inhabitants per $km^2$).

Six villages are concerned by the re-settlement plan according to Tan Uyen District's and NCPC's documents (NCPC, 2010). The resettlement plan is complemented by two large-scale irrigation projects. The first channel one will carry water on approximately 6 km from the to Phieng Luc and Phieng Bay's paddy fields, while the second one will carry water on about 4 km from the to Bai Pa Tra peninsula, where large-scale terracing works should also be supported if necessary. Bai Pa Tra, the new district centre, is a relatively flat, small peninsula situated a few hundred meters North-West from Phieng Luc on the opposite bank of the Nam Mu River. This area is currently part of Phieng Luc's territory. Farmers exploit it for cropping maize on its river shores, cassava and soybean on its flat-land or gentle slopes. No paddy fields are currently in place because of the lack of streams supporting sufficient water.

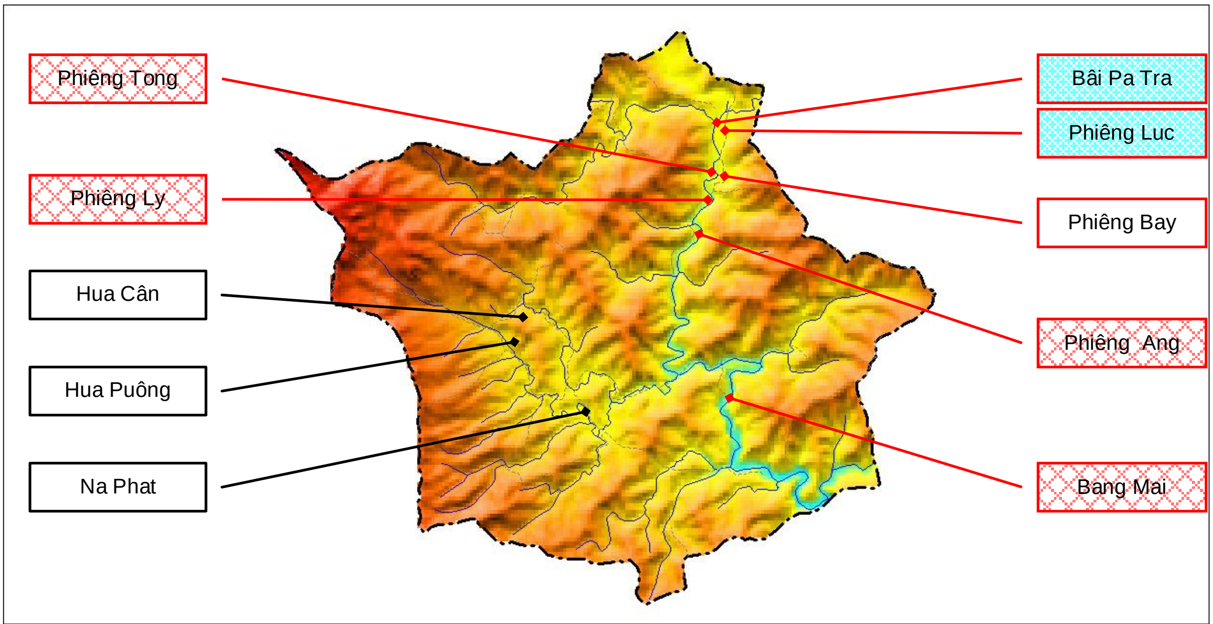


**Figure 8 :** Impact of the dam and re-settlements. Red borders: losses of land; black borders: no losses of land; red shading: re-settled villages; blue shading: resettlement villages. Source: this study, 2010.

*Reduced surface available per farmer and changes in the type of land available*

In Phieng Luc, the dramatic increase in local population density is likely to affect both native and resettled farmers who will globally have access to less land. As for now the land sharing modalities are not known, it is difficult to assess the type of land and surface each farmers will have access to through this process. However it is certain that the power-balance between newcomers and natives, and the capacity of local authorities to ensure a transparent redistribution process will greatly influence the fairness of the final result and thus the social cohesion. But beyond this land-sharing perspective in Phieng Luc, the traditional land-use rights that resettled farmers have on their current land is likely be a source of high inequalities and provokes tensions in the community, especially if the land granted to farmers fails to ensure their food security. This is true for crops but also and maybe even more for livestock forage and feedstuff, as the question of where to find feed to supply the four villages' flocks around Phieng Luc doesn't seem to be addressed by TUAD's resettlement strategy.

In Phieng Bay and Na Phat where land losses will occur without population displacement planned, the dam will dispossess some (Na Phat) or all farmers (Phieng Bay) of a part of their land. In the case of Phieng Bay, areas most touched are river shores and lowest paddy fields. Regarding paddy fields, the irrigation channels planned may compensate a part of losses in by increasing the surface of two season paddy fields. However farmers facing rice shortage due to the flooding of their field may compensate their losses either by intensifying rain-fed rice cultivation –which is likely to result in shortened fallows- for those who already owe upland-fields in the mountainous land at the south of the village; and/or expand rain-fed rice cultivation further South on abandoned fields. Further investigation is required to define who owe those lowest paddy fields, according to Phieng Bay's village chief and farmers, almost all households will be touched by paddy field losses but probably in various proportions.

The flooding of maize surfaces could result in a decrease in maize production that would seriously undermine livestock production and thus the whole livelihood strategy of a category of farmers. Thus it is expected that these latter will try to compensate their loss by expanding and/or intensifying their cassava production and/or relocating their maize production elsewhere (e.g. expanding further South on abandoned land or clearing marginal areas).

Regarding Na Phat, the dam will flood the paddy fields, river shores and bottom of valley gentle slope-land situated at the embouchure of the Hua Puong River, impacting relatively small percentage of the village's population.

*Increase of erosion risk due the new land-use pressure*

Based on field work, we estimate the erosion risk per category of land-use (Table 4). The highest risk of erosion is due to the annual crops on slopes such as Maize or Cassava, with an average of around 30 t/ha/yr. The figures of erosion risk within planted forest and tea plantation are very similar, with around 10 t/ha/yr. Then the shrubs and the natural forest have respectively an erosion risk of 3.5 t/ha/yr and 1.5 t/ha/yr (Table 4).

***Table 4:*** *Measurements of soil erosion risk in the studied watershed per land-use category*

| **Categories of land-use** | **Number of site measurements** | **Erosion risk (t/ha/yr)** | | |
|---|---|---|---|---|
| | | **Min** | **Max** | **Aver** |
| Annual crops on slopes (maize, cassava...) | 30 | 7,8 | 70,5 | 30,7 |
| Planted forest | 30 | 6,1 | 18,6 | 12,2 |
| Tea plantation | 30 | 3,5 | 14,1 | 10,1 |
| Shrubs | 30 | 1,2 | 5,5 | 3,5 |
| Secondary forest | 30 | 0,9 | 3,7 | 1,7 |
| Primary forest | 30 | 0,5 | 2,9 | 1,4 |
| Flat lands, Urbanization | -- | 0 | 0 | 0 |

Based on these figures, the erosion rate has been calculated for the whole Ban Chat watershed for different periods. The erosion risk is evaluated to 5.5 t/ha/hr in 2000, 6.4 t/ha/yr in 2004 and 6.7 t/ha/yr in 2009, which represents an important increase of more 20% on ten years. Two scenarios have been simulated (Fig. 9): (i) one is based on the evolution recorded between 2004 and 2009 (simul/2014); (ii) the second one is based on a special development of tea production (simul/tea).

For the first one, the land-use change is driven by the increase of the planted forest and a diminution of shrubs area. The second scenario doubled the tea plantation area and decrease the shrubs area with also a smaller increase of planted forest. For those two scenarios, the erosion risk is always increasing of more 10% relatively to the situationof 2009 (Fig. 10).

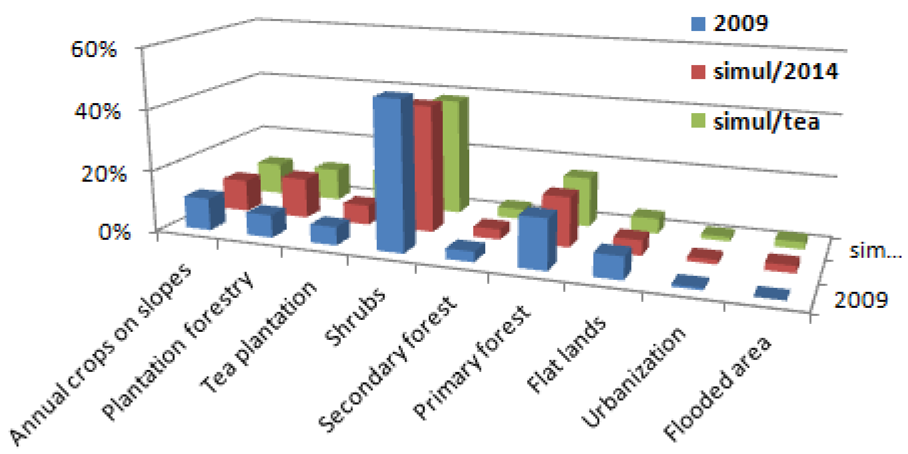


**Figure 9:** Simulation scenarios of land-use changes in the Ban Chat watershed after the dam building. Simul/2014: scenario after 5 years based on the present trends; simul/tea: scenario based on the tea production development. Source: this study, 2010.

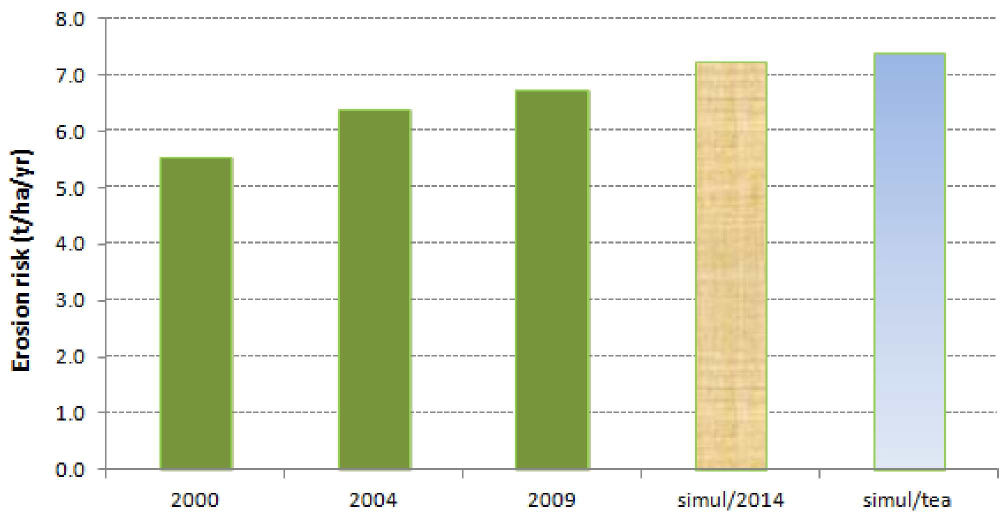


**Figure 10:** Erosion risk evolution from 2000 to 2009 within the Ban Chat watershed, and simulation of the erosion risk after the dam building. Simul/2014: scenario after 5 years based on the present trends; simul/tea: scenario based on the tea production development. Source: this study, 2010.

Over ten years, the total area of planted forest and tea planatation increased near 100%. This land-use change impacts obviously the soil erosion.

## 5. Conclusion

Finally, from before 2000 to 2009, there has been a rapid change in land-use within the Ban Chat watershed as oons as the early 2000's, before the dam building. The tea plantation has been doubled between 2000 in 2004, two years before the beginning of the dam building. It was the same trend for the planted forest with the first 6,000 ha in 2004 and more 12,000 ha in 2009. This extension of lands has been done in default of the fallow area (indicated shrubs) and the agricultural land area used for the annual crops. However, our field study at commujne level (in Nam Can Commune) has highlighted that even if the fallow area is large (with only 10 to 30% of crop-able lands), the pressure on the lands is huge for the farmers. Then this situation is often not taken into account by te authorities in charge of the r-settlements.

Beside the changes in land-use, another major problem is the on-going erosion process due to the increase of the agricultural surface for large agricultural companies. Clearly the risk of erosion is increasing by more than 20%, only because the indirect impact of the hydropower dam planning. Then it is argued that appropriate approaches are required to reverse this downward trend.

### 5.1. Elaborate an appropriate land-use assessment system for project monitoring and improved land planning before the dam construction

Current methods of land-use assessment from agricultural production induce often under-estimate the surface exploited for agriculture at the village level. Thus the land planning for hydropower project management will require designing a reliable information system and an appropriate corresponding methodology to assess agricultural land surface and location in order to allow an equal and objective planning management. Then the diffusion of such good data to local authorities could considerably improve their ability to elaborate land-planning consistent with the farmers' strategies and which doesn't undermine farmer's livelihood -avoiding the kind of situations that was created at the installation of Quyet Thien Forest Exploitation Company in the Nam Can Commune.

More research obviously is required to enhance our understanding of farmer's agricultural practices at the commune level and to integrate this knowledge in the design of information system for a sustainable land planning as soon as possible before the dam construction.

### 5.2. Identify project's opportunities for legitimacy and relevancy

Farmers from watersheds concerned by hydropower dam project, already face numerous agricultural challenges largely before the dam construction. And moreover additional ones are foreseen for farmers being resettled. With such a broad range of options for project exploration, designing a clear logical framework is required in order to select the most relevant ones. A proposed logical framework could include the following steps: (i) elaborate and validate a detailed farming system typology focused on soil, fertility, weeds and manure management practices; (ii) assess the impact of practices observed on land and water degradation and in particular in rainfed rice and cassava cultivation on sloping lands; (iii) identify possible alternatives using an integrative approach that replaces practices in the farming system context; (iv) evaluate the potential of each practices to provide environmental or other type of services and identify potential buyers and/or partnerships with local authorities, companies or other stakeholders; (v) evaluate the financial feasibility of alternatives identified for each farming system in concern; and (vi) based on the results of each step select a set of alternatives to be explored by the project.

All steps should involve as much as possible local stakeholders –possibly using participatory approaches- in order to ensure project's legitimacy and the relevancy of its proposals.

**Acknowledgement**

The authors particularly thank the provincial authorities of Lai Chau, of Tan Uyen and Than Uyen Districts. Thanks to all farmers in Nam Can Commune who patiently answered our questions and made the fieldwork a highly enjoyable time. The first author expressed a special thanks to the Prof. Simon Pomel from Bordeaux University who provided scientific guidance and friendly support from the beginning of his Master thesis in 2008, and without whom the following paper and the on-going PhD wouldn't be what it is. At last, special acknowledgements of financial support is attributed to: the French Embassy at Hanoi through the Master and PhD scholarships, the University of Toulouse and AUF through the agreement between the Son La Province and the Région Midi-Pyrénées, the IWMI-IRD through the MSEC research program.

7th conference ASAE ("*Meeting the Challenges Facing Asian Agriculture and Agricultural Economics Toward a Sustainable*"), Hanoi, 13-16 October 2011. Accepted for oral presentation

**Bibliography**


Bach H, Clausen TJ, Dang TT, Emerton L, Facon T, Hofer T, Lazarus K, Muziol C, Noble A, Schill P, Sisouvanh A, Wensley C, Whiting L (2011). From local watershed management to integrated river basin management at national and tyransboundary levels. *Mekong River Commission,* Lao PDR, 48 p. ISBN 978-9932-412-04-4.

Bach Tan Sinh, 2009. Strategic environmental assessment of the hydropower master plan in the context of the ppower development plan VI.

Bohlen C., Lewis L.Y., 2009. Examining the economic impacts of hydropower dams on property. *J Environmental Management*, 90: S258-S269.

Brown P.H., Magee D., Xu Yilin, 2008. Socioeconomic vulnerability in China's hydropower development. *China Economic Review*, 19: 614–627.

Carro A., 2010. First evaluation of the situation of agriculture, forestry and other land use in Nam Can Commune (rainy season of 2010). OPPORTUNITIES FOR ECONOMIC INCENTIVES TO PROMOTE SUSTAINABLE LAND AND WATER MANAGEMENT IN THE SLOPPING LAND OF SOUTHEAST ASIA, BMZ Project / IRD Contribution, Master2 internship, SFRI, Hanoi, Vietnam: 85 p.

Castella J-C., Dang Dinh Quang, 2002. Doi Moi in the Mountains: Land use changes and farmers livelihood strategies in Bac Kan Province, Vietnam. *The Agricultural Publishing House*, Hanoi, Vietnam, 283 p.

Castella J-C., Boissau S., Trung T.N., Quang D.D., 2005. Agrarian transition and lowland-upland interactions in mountain areas in northern Vietnam: application of a multi-agent simulation model. *Agricultural Systems*, 86(3): 312-332.

Clement F., Amezaga J.M., Orange D., Tran Duc Toan, 2007. The Impact of Government Policies on Land Use in Northern Vietnam: An institutional approach for understanding farmer decisions. IWMI Research Report 112. Colombo Srilanka. URL: http://www.iwmi.cgiar.org/Publications/IWMIResearchReports/PDF/PUB112/RR112.pdf.

Clement F., Orange D., Williams M., Mulley C., Epprecht M., 2009. Drivers of afforestation in Northern Vietnam: Assessing local variations using geographically weighted regression. *Applied Geography*, doi:10.1016/j.apgeog.2009.01.003: 1-16.

Dao, N. 2010. Dam development in Vietnam: The evolution of dam-induced resettlement policy. *Water Alternatives* 3(2): 324-340.

Duflo E., Pande R., 2007. Dams. *The Quarterly Journal of Economics*, 122(2): 601-646.

Dumont R., Mazoyer M., Dufumier M., 1999. Compared Economics research. *Handbook for Agrarian System Diagnosis,* FAO.

Echolms, 1997. Spreading deserts: the hand of man. *Word Watch Paper* (13). Word Watch Institute. Washington DC, 40 p.

King P., Bird J. Hass L., 2007. The current status of environmental criteria for hydropower development in the Mekong Region. *WWF-Living Mekong Programme*, Vientiane, Lao PDR.

Lal R., 1998. Soil erosion impact on agronomic productivity and environment quality. *Critical Reviews in Plant Sciences*, 17: 319–464.

Le Trong Cuc, Rambo A.T. (Eds.), 2001. Bright Peaks, Dark Valleys. A Comparative Analysis of Environmental and Social Conditions and Development Trends in Five Communities in Northern Vietnam's Northern Mountain Region. The National Political Publishing House, Hanoi : 350 p.

Lestrelin G., Giordano M., 2006. Upland development policy, livelihood change and land degradation: interactions from a Laotian village. *Land Degradation & Development*, 18(1): 55-76.

Maglinao A.R., Leslie R.N. (Eds), 2001. Soil erosion management research in Asian catchments: methodological approaches and initial results. Proceedings of IWMI-ADB project annual meeting and 5e MSEC assembly, Semarang, Central Java, Indonesia, 7-11 November 2000: 275 p.

Maglinao A.R., Valentin C., Penning de Vries F. (Eds), 2004. From soil research to land and water management: harmonizing people and nature. Proceedings of IWMI-ADB project annual meeting and 7e MSEC assembly, Vientiane, Laos, 2-7 December 2002: 250 p.

Nguyen Van Thiet, Pomel S., Pham Quang Ha, Tran Duc Toan, Orange D., 2008. Optical analysing techniques for soil erosion evaluation. *Science and Technology Journal of Agriculture & Rural Development*, 07/2008, The Agricultural Publishing House, Hanoi, Vietnam: 42-46.

Orange D., Noble A., 2010. Technical methods and tools for integrated land and water management, to deal with issues related to conservation and utilization of land and water resources and systems. In: e-Conference on "Integrated Land and Water Resources Management in Rural Watersheds", 2 Nov.- 4 Dec. 2009, *FAO Regional Office for Asia and the Pacific* (UNESCAP, APWF, IWMI, GWP), 8 p.

Orange D., Tran Duc Toan, Nguyen Duy Phuong, Nguyen Van Thiet, Salgado P., Clement F., Le Hoa Binh, 2008. Different interests, common concerns and shared benefits. *LEISA Magazine*, 24(2): 12-13. + Chinese version.

Roose E., 1994. Introduction à la gestion conservatoire de l'eau, de la biomasse et de la fertilité des sols ( GCES ). FAO, Bulletin pédologie, FAO. http://www.fao.org.

Scherr S.J., 1999. Soil Degradation: A threat to developing-country food security by 2020? *Food, Agriculture, and the Environment Discussion Paper* 27. Washington D.C.: IFPRI.

Sternberg R., 2010. Hydropower's future, the environment, and global electricity systems. *Renewable and Sustainable Energy Reviews*, 14: 713–723.

Tognetti S., Johnson N., 2008. Ecosystem services from improved soil and water management: creating a return flow from their multiple benefits. *CGIAR Challenge Program on Water and Food*.

Tran Duc Toan, Orange D., Podwojewski P., Do Duy Phai, Thai Phien, 2003. Erosion control within a cultivated sloping land in North Vietnam. China Symposium 2/Soil quality and evolution mechanism and sustainable use of soil resources, ISSAS/ Yingtan, Jiangxi Province, China, September23 -28 2003.

Tran Duc Vien, 2003. Culture, Environment, and Farming Systems inVietnam Northern Mountain Region. Southeast Asian Studies 41: 180-205.

Tran Duc Vien, Rambo A.T., 2001. Social Organization. In: Le Trong Cuc, Rambo A.T. (Eds.), Bright Peaks, Dark Valleys. A Comparative Analysis of Environmental and Social Conditions and Development Trends in Five Communities in Northern Vietnam's Northern Mountain Region, The National Political Publishing House, Hanoi : 177–208.

UNEP, 2010. United Nations Environmental Program. http://www.unep.org

Valentin C., Agus F., Alamban R., Boosaner A., Bricquet J.P., Chaplot V., de Guzman T., de Rouw A., Janeau J.L., Orange D., Phai Do Duy, Podwojewski P., Ribolzi O., Silvera N., Subagyono K., Thiébaux J.P., Toan Tran Duc, 2008. Runoff and sediment losses from 27 upland catchments in Southeast Asia: Impact of rapid land use changes and conservation practices. *Agriculture, Ecosystems and Environment*, 128: 225-238.

Wani S.P., Sreedevi T.K., Pathak P., Singh P., Singh H.P., 2001. Integrated watershed management through a consortium approach for sustaining productivity of rainfed areas: Adarsha watershed, Kothapally, India, Andhra Pradesh: A Case study. Paper presented at the Brainstorming Workshop on Policy and Institutional Options for Sustainable Management of Watersheds, 1-2 November 2001, ICRISAT, Patancheru, Andhra Pradesh, India.

WCD, 2000. World Commission on Dams. Dams and development, a new framework for decision-making. Earthscan, November 2000.