MSEC: An Innovative Approach for Sustainable Land Management in Lao PDR

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Introduction

Lao PDR, as well as five other Asian countries, and IRD participate to the Management of Soil Erosion Consortium (MSEC) coordinated by IWMI. In addition to a direct participation to research and training activities, IRD play an efficient role in favouring relations between the research institutions and the universities both in Laos and in Europe. It can thus favour the establishment of a continuum between academic and adaptive research with and for the farmers.

The project primarily aims at developing and promoting sustainable and acceptable community-based land management options in agricultural catchments through a participatory and interdisciplinary approach. The study site in Lao PDR is the Houay Pano catchment (64 ha) located in Ban Lak Sip, Luang Phrabang District.

The objective of this annual report is to briefly present the highlights of research and training operations of the project in 2003.

Research Results

Socio-Economic Aspects

Village history and ethnic groups

Ban Lak Sip was formed by the relocation of five neighbouring villages beginning after the 1975 revolution when population resettlement policies were introduced. In 1962, three families from neighbouring areas founded the village of Houay Oup on the actual site of Ban Lak Sip. Progressively, other families settled, often originating from Northern provinces and fleeing the war. Since 1975, the village renamed Ban Lak Sip, underwent three major immigration phases. In 1975-76, nine families living in the very neighbouring village of Houay Tong was moved to Ban Lak Sip along with two families from another nearby village (Ban Kiupapai). In 1982-83, twelve families of Ban Naxone, located less than one kilometer away were moved to Ban Lak Sip. Finally, in 1996-97, twenty four households living in Houay Nokpit (two hours into the mountains) were moved to Ban Lak Sip. By 2003, the village community had reached 503 inhabitants (Table 1).

The main ethnic group constituting the village community is the Khamu group with 87 % of the population. According to ethnographic literature, the customary means of livelihood of this group are mainly oriented towards activities linked to upland forested areas: shifting cultivation of upland rice, collect of timber and non-timber forest products, hunting... These activities still remain fundamental features of the current production system. However, a recent tendency seems to be in the development of alternative production activities such as vegetables cropping, tree plantation (teak and banana), livestock farming and seasonal factory labour.

Table 1. Some socioeconomic attributes of the project site

General summary

Households	93
Population	503
Women	247
Average household's size	5.4

Ethnic distribution

Households - Persons (Women)

Khamu	82 - 437 (216)
Lao	9 - 56 (26)
Yao	2 - 10 (5)

Age group

< 7 years	16 %
7 to 15 years	25 %
16 to 50 years	53 %
> 50 years	6 %

Education level of the households' heads

Illiteracy	14 %
Primary school	50 %
Secondary school	29 %
High school	7 %

Population policy and population density

Since 1975, the Lao rural development policy has consistently attempted to provide access to services for everyone including the most remote populations. Upland populations have been strongly encouraged to settle along roadsides and riverbanks in order to practise irrigated cultivation and to benefit from the services (medical, educational, etc.) provided by the State. Thus, resettlements of highland villages near the communication axes and gathering of neighbouring villages have been implemented as a way to fulfil the State's objectives of rural development.

In Ban Lak Sip, the three immigration phases consecutive to the national policy have led to a high average population growth rate per year of 7.3 % for the whole period 1962-2003. These resettlements have induced a rapid increase of population density within the village land. The population density reaches over 100 inhabitants per km square as early as 1998 (Figure 1).

Figure 1. Population density of Ban Lak Sip, 1998

Land policy and land allocation program

Since the 80's, the Lao government identified as development priorities for the upland areas the need to settle farmers on allocated lands and to stabilize shifting cultivation practices. To fulfil these objectives, a set of decrees and instructions on agricultural and forest lands management have been issued to support the national land use planning and land allocation program which is effectively undergoing in the country since 1989.

In the case of Ban Lak Sip, it is embodied in an agreement in 1995 between village authorities and the national authority represented by the District Agriculture and Forestry Office and other financial and planning officers. This agreement determined the boundaries of the land available for agrarian purposes, while the remaining land (old fallows, pre-existent forests, summits and riparian lands) has been classified in different types of protected forests and banned from clearing (along with different restrictions of use). The area available for agricultural activities has been reduced to 136 hectares (one third of the whole village land of 433 hectares) with a maximum of three plots allocated per household, while 281 hectares have been classified as protected and production forests.

An artificial land shortage

Consequently, to the combined effects of the land reform and the population dynamics, the average area owned per household has been reduced by one third between 1994 and 1995, decreasing from 3.9 to 2.7 hectares (Figure 2). This land area limitation affected particularly the areas used for shifting cultivation mainly located in the higher parts of the village land.

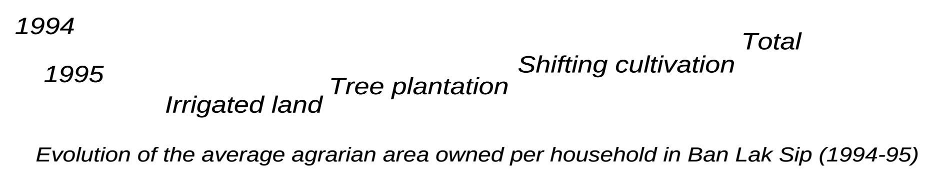

Figure 2. Land allocation for each household in Ban Lak Sip, 1994-1995

Such a reduction in the land available for shifting cultivation can be considered, without development of alternative production activities, as a main driving force for a change towards more land-intensive cropping practices, particularly through shortening of fallow period and lengthening of cropping period.

More labour-intensive practices

Both labour time and number of workers allocated to shifting cultivation activities have been gradually increased since 1990, with a particular emphasis after the land allocation of 1995 (Figure 3). The same trend is happening in the total time of work per year, as an expression of the intensification and the development of alternative activities. However, the workforce being a finished quantity, these dynamics of labour-led intensification are likely to be followed by a reinforcement of the land pressure to compensate the lack of labour, promoting a real cycle of degradation of both the natural resources and working conditions. As a result livelihoods are threatened because workload tends to be unsustainable.

Figure 3. Work time allocation for shifting cultivation, 1990-2003

More land-intensive practices

Since 1970, the cropping and fallow period durations appear to evolve in the way of an intensification of the land use. But if the shortening of fallow period started several years ago due to the continuous increase of population density, the lengthening of cropping period is a more recent tendency that can be correlated with the land reform implemented in 1995 (Figure 4). Without capital invested in soil conservation techniques and in agricultural inputs (fertilizers, herbicides...), this evolution of the shifting cultivation towards a more land-intensive practice is recognised by many scientists as a main cause of soil erosion, soil fertility depletion, weed invasion, and consequently, decrease of crop yields.

Evolution of the cropping and fallow periods durations in Ban Lak Sip since 1970

Figure 4. Evolution of the cropping and fallow periods in Ban Lak Sip, 1970-2003

Critical decrease in crop productivity

As a consequence of the shortening of fallow period and the lengthening of cropping period, the upland rice crop yields record a clear decline observed since 1990 (Figure 5). Such yield decline, particularly for upland rice, which constitutes a fundamental product for the upland populations' self-subsistence, is likely to lead these populations to increase their labour input and to develop alternative activities in order to avoid disastrous food shortage. The yield decrease reflects weed invasion, soil erosion and soil fertility depletion, namely environmental degradation.

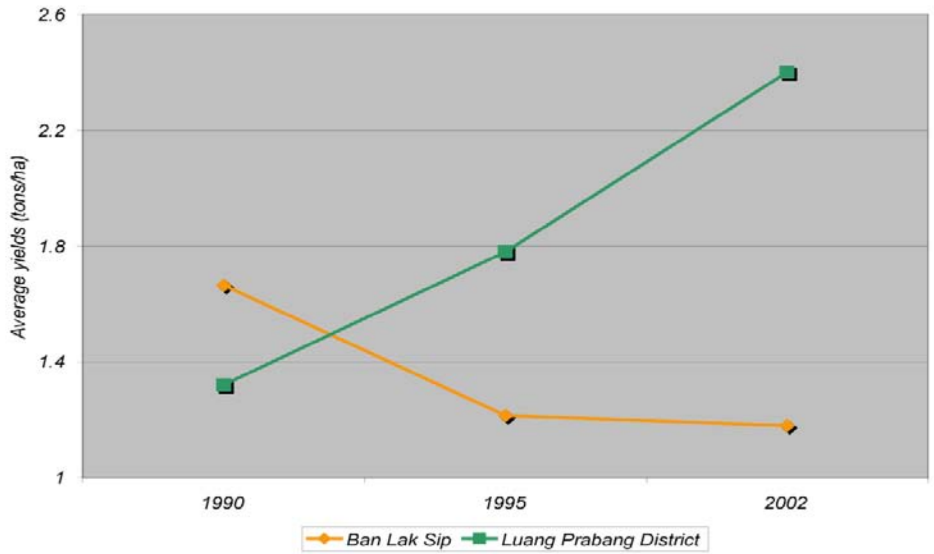

Figure 5. Compared evolution of the upland rice yields in Ban Lak Sip and the Luang Prabang District

Biophysical Characteristics

Rainfall

In 2003, yearly rainfall was much lower than the two previous years. Moreover, the rainfall in May, when the soils were bare, were very low compared to the three previous years. Except for April and September, the monthly rainfall was below average calculated over the five-year period (Table 2 and Figure 6).

Table 2. Monthly rainfall recorded in the Houay Pano catchment (1999-2003)

	1999	2000	2001	2002	2003	Average
Jan	-	-	-	41	14	**28**
Feb	-	-	-	2	21	**12**
Mar	-	-	150	11	70	**77**
Apr	-	-	47	43	169	**86**
May	-	244	446	231	71	**248**
Jun	370	324	236	245	247	**284**
Jul	139	236	378	424	164	**268**
Aug	260	175	449	323	259	**293**
Sep	213	219	298	200	280	**242**
Oct	-	32	208	140	33	**103**
Nov	-	-	5	79	1	**28**
Dec	-	-	5	68	1	**25**
Total	982	1230	2222	1807	1330	**1694**

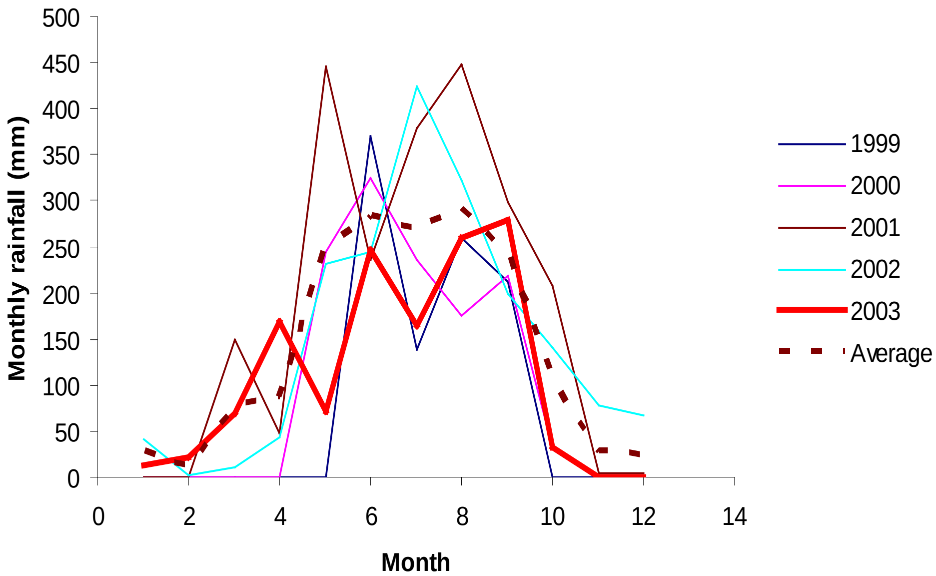

Figure 6. Monthly rainfall in Houay Pano catchment, 1999-2003

Land use

Since 1999, a detailed land use map is prepared. Due to the reduction in the fallow period to two years, upland rice is gradually replaced by Job's tear and corn. Figure 7 shows the land use map of the catchment in 2003.

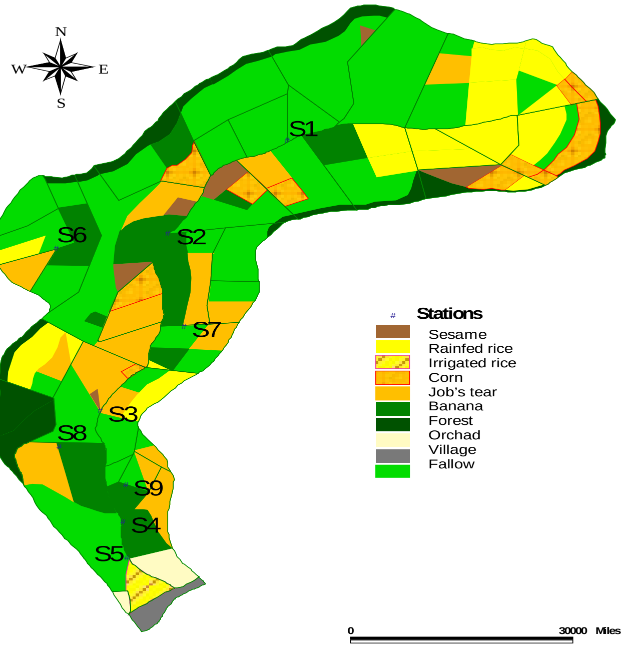

Figure 7. Land use map of Houay Pano catchment, 2003

Runoff and water erosion

Sediment yields

Some remarks can be drawn from the runoff and water erosion data collected in 2003 (Table 3):

- In contrast with what is usually observed, runoff percentage is much lower from small catchments (<1ha) that from larger catchments (<10 ha). This may result by the fact that infiltration is higher on steep and upper slopes than on lower and gentler slopes. Field observations indicate that there is an important throughflow along the hillslopes. Water infiltrated in the upper steep slope exfiltrates in small springs on lower slopes before the hill bottom, causing a second rill generation.
- Water erosion was much lower than for the previous years. In first analysis, this is due to lower yearly rainfall amount, and more specifically in very low rainfall in May.
- Given these low amounts, it is difficult to establish firm comparisons among the four treatments (S6, S7, S8 and S9). The so called 'traditional system' (S7) produced very limited soil erosion (.05 t ha^1) compared to last year (5.74 t ha^1). This has to be ascribed to the fact that because this field has been under cultivation

for the third consecutive year, weed infestation could not be controlled and the soil surface was covered and protected from raindrop impact. In contrast, weeding operations were very effective on S8, leaving bare soil surface under crops, thus an higher amount of soil erosion. As for 2002; the treatments in S6 and S9 were effective to control soil erosion.

Table 3. Runoff and soil erosion (bedload and suspended load) measured from the Houay Pano catchment and sub-catchments in 2003.

Catchment	Systems	Area	Bedload	Suspended load	Total	Runoff
		ha	t ha^{-1}	t ha^{1}	t ha^{1}	%
S1	Traditional	19.6	0.62	1.76	2.38	31.2
S2	Traditional	32.8	0.02	1.57	1.59	25.9
S3	Traditional	51.4	0.08	0.92	1.00	23.5
S4	Traditional	60.2	0.55	1.00	1.55	28.3
S6	Improved fallow	0.6	0.00	0.03	0.03	0.12
S7	Traditional	0.62	0.00	0.05	0.05	0.39
S8	Contour planting	0.567	0.41	0.70	1.11	3.75
S9	Mulch & No Tillage	0.727	0.00	0.07	0.07	4.39

Interril erosion

Interrill erosion was investigated using 21 metallic bounded plots with a surface of 1 and 2.5 m^2 installed in a small catchment (0.6 ha) under “Traditional” cultivation practices (catchment S7) consisting of the present ‘slash and burn’ system, with no input and reduced fallow period (1-3 years) (Figure 8). Because runoff, which is the driving mechanism for nutrient and sediment transport in landscapes, may highly vary according to topography, soil characteristics (including surface crusts) and land use plots were installed since the onset of studies to survey the effect of each of these environmental factors. In 2002, both soil and land-use effects were firstly investigated. It has been shown that soil types have a predominant role in controlling runoff and erosion, thin eroded soils exhibiting higher erosion rates. In 2003, our objective was to evaluate the impact of the slope position on the inter-rill erosion. Bounded plots were installed from downslope to upslope position of a hillslope under Alfisols and rice production. The methods included the collection of water samples, drying, evaluation of soil humidity and soil surface coverage.

Runoff varied from 0 to 60 % with maxim median at midslope position. The sediment concentration SC varied from 0 to 120 g/l. Maximum SC values were observed in the degraded forest where kinetic energy of big drops from the canopy is hardly decreased by a very meagre understorey. In hillslope, SC decreased from upslope to downslope from 5.5 to 2.5 g l-1. Soil losses also decreased from upslope to downslope. Additional results revealed that runoff, SC and SL were half on 2.5m^2 than on 1m^2 plots. Mean erosion at 1m2 was 12.2 T ha^{-1} year^{-1} on 1m2 and only 5.5 ha^{-1} year-1on 2.5 m^2. Higher variability characterised 1m^2 plots.

Figure 8. Sub-catchment S7 where bounded plots were installed

Gully erosion

At the onset of the rainy season, 29 rills were reported in Houay Pano catchment with a total length of 3,410 m. During the 2003 season, rainfall event did not generate new rill even increased rill length. These initial rills were however deepened. The total erosion rate by rill erosion in 2003 was 0.11 T/ha which is very low if compared with rill erosion in 2001 (2.4 T/ha) and 2002 (1.5 T/ha) (Table 4).

Greater total rill erosion (T) in 2003 mainly occurred within bigger sub-catchments (1, 3 and 4) with the exception of sub-catchment 2. Catchments 1 and 9 showed higher rates. These results allowed quantifying inter-rill and rill erosion at the catchment scale. It appeared that rill erosion was much lower than inter-rill erosion. This surprising result compared to 2001-2002 investigations may be explained by an higher soil surface coverage when greater rainfall events occurred. Further investigations will aim at better understanding such differences.

Tillage erosion

The analysis of data on tillage erosion had already clearly shown that tillage erosion increases exponentially with slope gradient. The model developed to predict tillage erosion based on the type of cover, the weeding tool and the frequency of weeding operations was used to reconstruct for each plot of the catchments the cumulative tillage erosion or deposition since the early 60’s.

It appears that tillage erosion remained very low till the early 70’s. It sharply increased in the mid 80’s with the change in the cropping systems due to the reduction of the fallow period (see below). Because of land shortage, fallows on steep slopes are more frequently turned in to cultivation. As a result, tillage erosion has increased substantially over time in the last 15 years (Figure 9).

Table 4. Rill erosion in Houay Pano sub-catchments (1 to 9) from 2001 to 2003.

		2001		2002		2003	
Sub catchment	**Surface (ha)**	**Total**		**Total**		**Total**	
		ton	Ton ha^{-1}	ton	Ton ha^{-1}	ton	Ton ha^{-1}
1	19.6	37.35	1.90	59.16	3.02	3.90	0.20
2	13.6	1.15	0.08	3.28	0.24	0.00	0.00
3	16.7	107.34	6.42	0.00	0.00	1.38	0.08
4	8.2	0.00	0.00	0.00	0.00	1.04	0.13
6	0.6	0.43	0.67	1.69	2.65	0.00	0.00
7	0.6	0.00	0.00	5.37	9.25	0.00	0.00
8	0.7	0.00	0.00	10.71	14.48	0.03	0.03
9	0.7	0.00	0.00	9.27	12.69	0.14	0.19
Sum		146.27		89.49		6.49	
Average		18.28	**2.43**	11.19	**1.49**	0.81	**0.11**

Figure 9. Tillage erosion as affected by slope

Improving cropping systems

Crises of the slash and burn systems and possible alternatives

As shown by many interviews with the farmers, cross-checked with aerial photographs, land use change in the Houay Pano catchment has followed four stages since the 60's:

1. Stage 1. Clearing with axe /hatchet, one burn, sowing rice, one/two weedings with ouèk, large fields, large rice store houses.

2. Stage 2. Clearing with matchete, burn, piling, re-burn, sowing rice, first weeding, scraping the soil with ouèk; one/two more weedings no tillage.
3. Stage 3. Clearing with matchete, burn, piling, reburn, some tillage with tjok, sowing rice, two/three weedings last one no tillage, *Mimosa invisa*
4. Stage 4.– End of upland rice cropping - Clearing with matchete, burn, piling, reburn, more, deeper tillage with tjok, delayed sowing, three/four weedings last one no tillage.

These changes were accompanied with a fragmentation of fields, the cultivation of lower slopes with teak (1987), bananas (1991), the replacement of upland rice by Jobs' tears (1999), the plantation of fruit trees, vegetables, the development of fishponds (>2000), the introduction of goats (2002) and related fencing (2003), the cultivation of mix Jobs*sesame, rice*sesame, maize*beans, bananas (cut back) sesame (2003).
The tested innovative systems tend towards systems with grazing, less fire, less weeding.

Testing innovative land use systems

Farmers usually do not identify soil erosion as a main problem in upland farming; instead, they consider weed competition the single most serious constraints to upland rice cropping. Acute weed problems combined with the more hidden impact of erosion are severe threats to agricultural development in Laos. The objective of this study was to compare four farming systems in separate minicatchments (1 ha) each one equipped with a sediment trap and a water sampler. Soil erosion, crop productivity, labour input and weeds have been quantified and evaluated under the rotational slash and burn cultivation system and compared with three promising alternative farming systems. The study site is part of the Houay Pano watershed near Ban Lak Sip, Luang Prabang district.

Farmers in the village practice upland rice-based cultivation in rotations of one to three years of bush fallow and one year of rice or Job's tears (*Coix lacryma Jobi* L.). Because of more intense cropping and reduced fallow period, farmers reported that crop yields have declined to about half of the twenty years ago yields of 3 to 4 t.ha-1, leading to recurrent rice shortages.

Improved fallows are the deliberate planting of fast-growing species, usually legumes, for rapid replenishment of soil fertility and weed suppression. Since 1990s, research on improved fallow is based on sustainability considerations particularly (i) short-term improved fallow; (ii) sequential versus simultaneous systems; (iii) dry seasons crops; (iv) woody versus herbaceous fallows.

Types of fallow

Natural fallows are early succession stages of secondary vegetation after a cropping period. Natural woody fallows are the backbone of shifting cultivation systems.

Enriched fallows are those where certain tree species are planted at low densities into natural fallows to produce high-value products such as fruits, medicines, or high-grade timber to provide economic benefits during the fallow period.

Improved fallows are very different; they consist of deliberately planted species, usually legumes. They cover entire fields in a farm. Improved fallow with herbaceous legumes or grasses are commonly called green manures or cover crops. E.g. in our treatment "Mulch, no till" the cover crop is Ruzi grass. Improved fallows with woody legumes are usually called by the tree used. E.g. in our treatment there are Pigeon pea fallow and *Crotalaria* fallow.

In contrast with other projects in Laos where testing of farming system is carried out on a plot or field scale, MSEC uses the watershed or catchment scale. This implies that landscape features as topography, gullies and rock outcrops are better accounted for. Practically it meant that all farmers cultivating within such a watershed had to apply the same farming system.

Four farming systems are studied in separate mini-catchments since 2002:

- ♣ Rotational slash and burn. This is the conventional system with reduced fallow periods ranging from 1 to 3 years.
- ♦ Improved fallow. Recommended by the Integrated Upland Agricultural Research Project (IUARP), such systems aim to enrich the poor bush fallow with additional biomass, early ground cover and extra litter to improve the soil and suppress weeds in a short period. Improved fallows seem to be adaptable by farmers in the region within a limited period. The legume trees tested are Pigeon Pea (*Cajanus cajan* (L.) Huth. and *Crotalaria* micans Link (syn. *Crotalaria anagyroides*).
- ♥ Improved fallow with contour planting. The same legumes trees are used in combination with contour strips of pineapple. Contour planting is recommended by the Asialand/Sloping land project.
- ♠ Mulch planting without tillage. No-till and direct sowing in dead mulch of Ruzi grass (*Brachiaria ruziziensis* Germain & Evrard) with limited use of glyphosate as recommended by the CIRAD (French Research Centre for Agriculture and Development). During the dry season, the cover crop Ruzi grass acts as a grazed fallow. The farmers would adopt this system only under better economic conditions.

Labour

Compared to the tradition system (S7) with about 220 days ha^{-1}, the systems in S6 (improved fallow) and even more S9 (mulch planting with no tillage) require much less labour (Table 5).

Table 5. Normalized labour required (day ha^{-1}) for the cultivation of Jobs'tear, Houay pano, 2002-03

Operation	**S7**	**S7**	**S6**	**S6**	**S8**	**S8**	**S9**	**S9**
	2002	2003	2002	2003	2002	2003	2002	2003
Field preparation	41	59	53	23	77	44	29	33
Burning	1	2	1	2	1	2		
Second clearing	26	0	70	21	31	39	63	
Frist weeding	36	39	34	26	19	46	16	26
Second weeding	38	67	2	36	6	15		
Tillage sub-total	142	167	160	108	134	146	108	59
Herbicide							5	18
Transport/Planting pineapple (2001)					56	33		
Replacing (2003)								
Planting main cereal crop	43	28	42	18	36	31	21	21
Planting cover crop			52	36	65	51	62	51
Harvest & transport	25	36	7	18	26	59	3	44
GRAND TOTAL	210	231	209	144	196	236	132	124

Yields

Some remarks can be drawn from the data obtained on rice and Job's tear yields (Table 6):

- Yields are higher on lower slopes and upper slopes for rice, which is the opposite for Job's tear. This may be due to water demand is higher for rice than for Job's tear and that Job'tear is less tolerant than rice to excess of water.
- Yields obtained by the Hmong farmers were much higher than for Khmu farmers. This can be ascribed to a different weeding strategy. Hmong farmers weed any time that they observe any weed regrowth while Khmus usually two or three times "only" during the cycle.
- Yields in S7 ("traditional system") were extremely low, reflecting the exhaustion of the soils and the weed invasion. As a result soil erosion was low (*cf.* above).
- Highest yields of Job's tear were observed on S8 (contour planting). This can be ascribed to an efficient weed control which limited competition between weeds and Job's tear but favoured soil erosion (*cf.* above).
- The difference in yields observed between S6 and S8 cannot be attributed to contour planting but rather to difference in weed control and also (and very likely mostly) to difference in soil fertility.
- Unlike *Crotalaria*, pigeon pea does not seem to compete with Job's tear (see differences among yields observed in pure stand and with *Crotalaria* and Job'tear).
- Ruzzi grass seems to have a beneficial effect on the yields of Job's tear.

Table 6. Grain yields (kg/ha) from crop cuts in Houay Pano

	2003	2002	2001
Rice			
Average catchment	1911	1856	969
all lower slope	2040		
all upper slope	1782		
Hmong	2985		
Jobs'tears			
Average catchment	1287	1781	1267
all lower slope	1189		
all upper slope	1386		
Station 6			
pure stand	782		
mixed with Pigeon Pea	981		
mixed with *Crotalaria*	619		
Station 8			
pure stand	2225		
mixed with Pigeon Pea	2122		
mixed with *Crotalaria*	2063		
Station 7			
pure stand	349		
Station 9			
pure stand	647		
mixed with Ruzi grass	1530		

Impact of rill erosion on yields

Comparison of yields measured in 'normal' soils and soils affected by erosion (rills and shallow landslide) show a clear impact of soil erosion, especially for shallow landslides (Figure 10). In the case of shallow landslide, the impact is more pronounced for Job's tear than for rice.

Regional study

Because soil scientists need to be able to make informed decisions at the regional scale, there is a crucial need to obtain spatial information on soil erosion. Fine studies at the small catchment level showed that soils are key factors that control soil erosion. The spatial knowledge of soil properties is indeed necessary to predict soil erosion. The estimation of erosion risks at the province level will request high precision maps.

The improvement of the map quality could be achieved by increasing the density of observations. This is the prevailing way. But, in many cases, increasing the sampling density is very costly especially in the case of large areas. Another possibility to improve the map accuracy is to use interpolation techniques that would minimize errors commonly produced during the map generation processes. In this study of the Luang Prabang province (19,149 km^2, northern Laos) we compared the

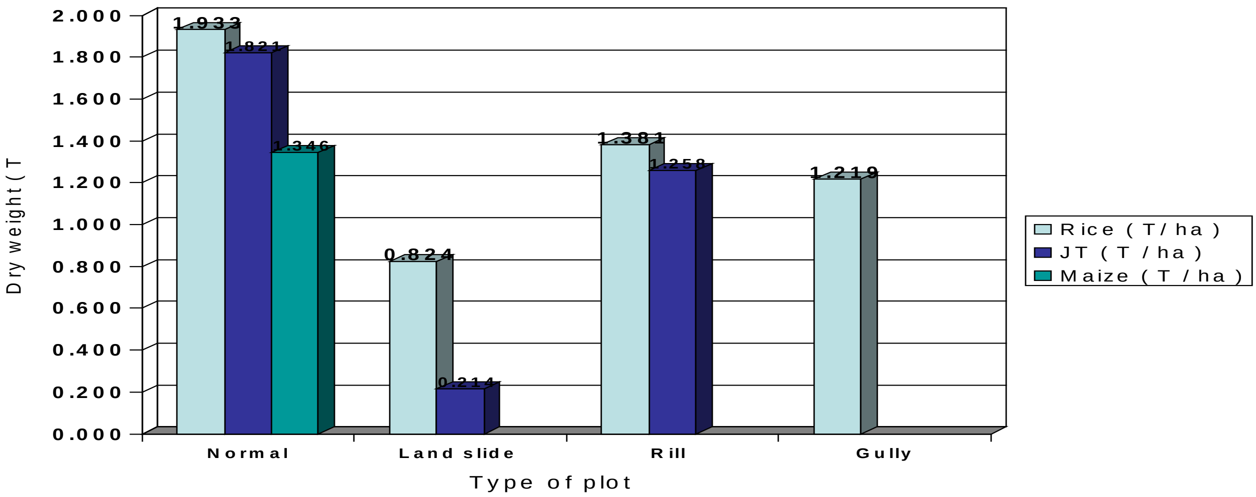

Figure 10. Yields of crops under normal soil and that affected by erosion

quality of soil properties maps for soil depth, pH, CEC, clay and carbon content using several interpolation techniques including inverse distance weighting, spline, ordinary and universal kriging, global polynomial and radial basis. The validation procedure was performed by using an independent data set.

Soil depth

The spatial variations of the soil depth are presented in Figure 11. Soil depth varies from 0.45 to 1.25 m with an average of 1.07 m. The higher depths are located along a north-east axis. A large area with shallow soils characterizes the center of the region. Some spots with depths lower than 0.6 meter are encountered in the valley bottoms of the center and south. This is surprising since valley bottoms tend to accumulate sediments eroded from hillslopes. One explanation is that the presence of coarse elements such as big stones did not allow field scientists to reach the soil bottom with the auger hole.

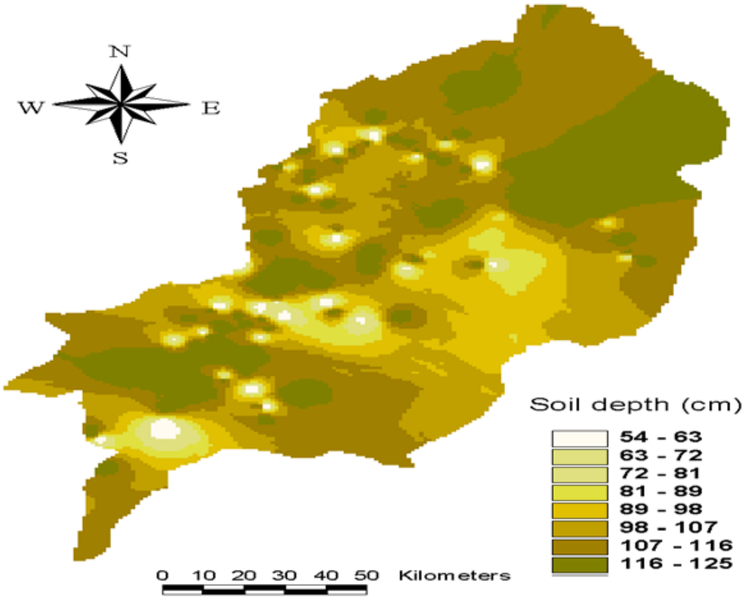

Figure 11. Soil depth map of the Luang Prabang province interpolated using 140 available data points by using inverse distance weighting (IDW) with 12 neighbors. Grid with a 1000-m mesh. Location of streams.

pH of A horizons

The spatial variations of the pH of A horizons are presented in Figure 12. The pH values range from 4 to 8 m with a mean of 5.6. Values gradually decrease from 8 in a limited area of the south-west to 4 in the north-east where deep soils are encountered. Beyond expectations, limits between pH values are globally perpendicular to the axis of main topographic structures. However, such a gradient could be associated to a gradient of agricultural; intensification along a similar axis, calcium inputs being preferentially added in the south.

Clay content of A horizons

The spatial variations of the clay content of A horizon are presented in Figure 13. Clay content varies from 5.5 to 51.2 % with an average of 25.2 %. Minimal values (less the 20 %) are mostly situated in the center east of the province where shallow soils were also observed. Greater contents occur in the south-west and the north-east of the region. Similarly, a high correlation exists between deep and clayed soils.

Carbon content of A horizons

The spatial variations of the carbon content of A horizons are presented in Figure 14. Carbon content varies from 0.015 to 3.99 % with an average of 1.83 %. The general distribution of carbon content is similar to this of the soil depth distribution, i.e. high concentrations along the north-east and a large area with low C content in the center of the region.

CEC of A horizons

The spatial variations of the CEC of A horizons are presented in Figure 15. CEC varies from 4.45 to 42.8 with an average of 15.2. The higher concentration is situated in the south-west of the region where high pH values were also observed.

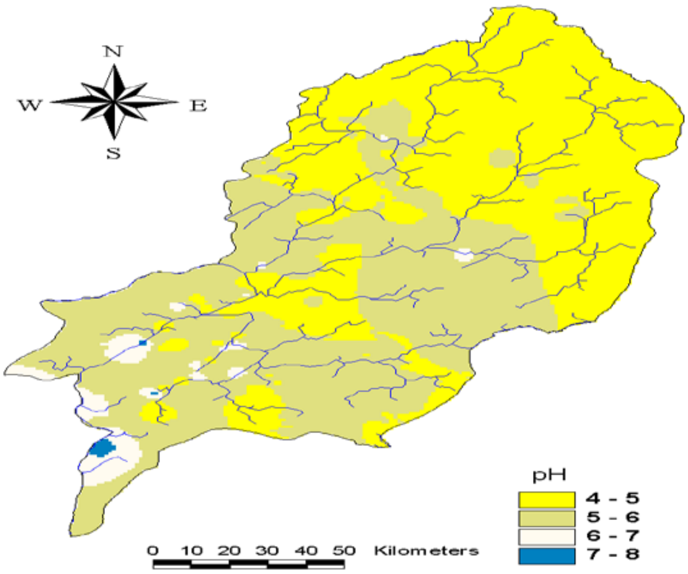

Figure 12. pH map of the Luang Prabang province interpolated using 140 available data points for surface A horizons by using inverse distance weighting (IDW) with 12 neighbors. Grid with a 1000-m mesh. Location of streams

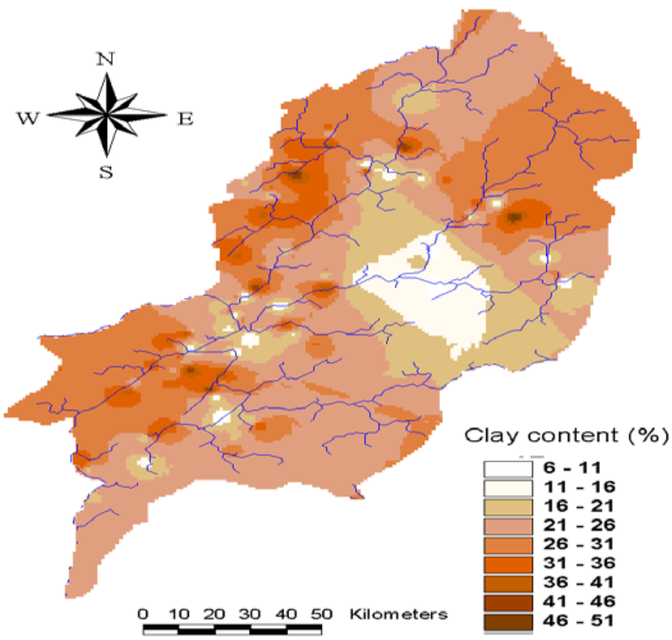

Figure 13. Clay content map of the Luang Prabang province interpolated using 140 available data points for surface A horizons by using inverse distance weighting (IDW) with 12 neighbors. Grid with a 1000-m mesh. Location of streams.

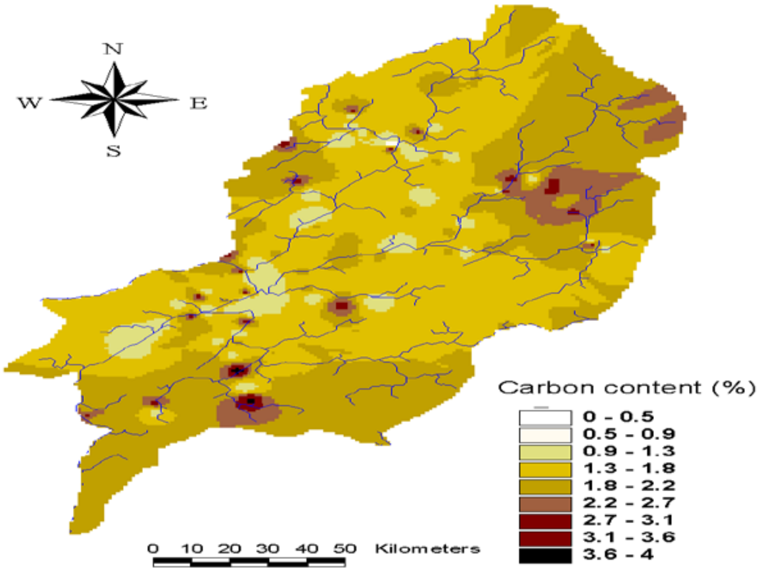

Figure 14. Carbon content map of the Luang Prabang province interpolated using 140 available data points for surface A horizons by using inverse distance weighting (IDW) with 12 neighbors. Grid with a 1000-m mesh. Location of streams.

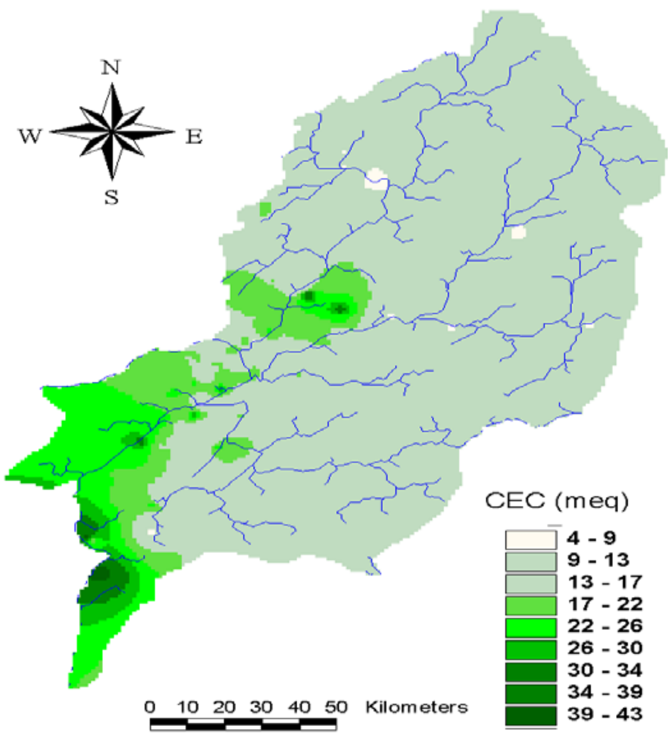

Figure 15. Total CEC map of the Luang Prabang province interpolated using 140 available data points for surface A horizons by using inverse distance weighting (IDW) with 3 neighbors. Grid with a 1000-m mesh. Location of streams.

For pH, CEC, clay and carbon (C) content for the surface A horizon as well as of soil depth (SD), mean errors (ME) and mean absolute errors (MAE) were the lower for IDW techniques. For instance, MAE for SD was of only 1.15 cm for IDW12. In the case of the carbon content MAE was 0.03%, i.e., 2% only of C average at the province scale.

Many authors already demonstrated the interest of geostatistics but on smaller areas or at lower sampling density. This is confirmed by additional results (not presented here) at lower sampling density (45 data points) showing that IDW was not the most accurate technique. In this case, global polynomial and kriging gave better results for all study soil properties.

Conclusion

The research activities cover a wide array of topics from vegetation cover and agronomy to isotopic water geochemistry. The working atmosphere is very stimulating and results in valuable data. These have been used to calibrate and validate hydrological and soil erosion models so that the experience gained in the Houay Pano catchment can be applied in other similar catchments. A peculiar attention is been paid to the impact of land use change scenarios upon soil erosion. This requires an integration of the data and knowledge collected in the field but also the expertise of various scientists from MSEC institutions (including IRD and IWMI). A special effort will be made to render the results accessible not only to the scientific community but to also to other stakeholders as the decision makers, and the farmers.

The next year will be another step with the continued testing of innovative technologies to limit on-site soil erosion and off-site impacts. This will strengthen the already existing links with the farmers of the Houay Pano catchment. Furthermore, the experience gained in this small catchment should be used to a much larger scale (the Nam Ngum river) in collaboration with Laotian institutions.

Training

Student Training

Seven Bsc and Msc-level students make their practical field works with NAFRI-IRD-IWMI in the Houay Pano catchment :

1. Thanong Kham Vanthongkham, soil science, BSc
2. Phengher Xaychou, soil science, BSc
3. Sengheo Rasaket, soil science and hydrology, BSc
4. Kongmany Thammavongxay, agronomy, BSc
5. Korrakanh Chanthavonsa, agronomy, BSc
6. Brice Dupin, soil science and agronomy, pre-practical training, ENGREF (Faculty of Rural Engineering and Forestry, Montpellier); January-July.
7. Charlotte Dumas de Rauly, agronomy, ENSAM (Faculty of Agronomy, Montpellier), March-August
8. Marie Alexis, soil scientist, MSc. student, Paris, a two-week mission in March.
9. Amen Arous, ecologist, MSc. student, Paris, a two-week mission in March

On-the-Job Training Workshops

1. 17-21 February, Vientiane, NAFRI. Topography: from field survey to DEM generation
2. 3-14 November ; Vientiane, NAFRI; Selection of optimal interpolation techniques at different scales .

Meeting

A meeting was held in NAFRI, 30th September with participants from Lao PDR, Thailand, Vietnam and France : “Land and Water Management Research in the uplands of South-East Asia” (Photo). A CD-ROM including all the presentations was prepared and distributed.

Main Related Publications

Papers

International

Chaplot V., Giboire G., Marchand P., Valentin C. accepted. Dynamic modeling for gully prediction under global change in northern Laos. *Catena*.

Huon, S., Bellanger, B., Bonté, Ph., Podwojewski, P., Valentin, C., Velasquez, F., Bricquet, J.-P., de Rouw, A., Girardin, C., submitted. Monitoring soil organic carbon erosion with isotopic tracers: two case studies on cultivated tropical catchments with steep slopes (Laos, Venezuela). *Advances in Soil Science.*

Janeau J.L., Bricquet J.P., Planchon O., Valentin C. 2003. Soil crusting and infiltration on steep slopes in northern Thailand. *European Journal of Soil Science*. 2003, 54(3):543-554..

Poesen, J., Nachtergale, J., Vertstraeten, G., Valentin, C., 2003. Gully erosion and environmental change. Importance and research needs. *Catena*, 50(2-4): 91-134.

National

Chaplot, V. Coadou le Brozec, E., Keohavong, B., Chanthavongsa, A., Valentin, C., 2003. Evaluation and prediction of linear erosion at the catchment scale. Cas of Houay Pano catchment (67 ha). *The Lao Journal of Agriculture and Forestry*, 6:56-68.

Chaplot, V., Tessier, J., de Rouw, A., Valentin, C, Xayyathip, K.,., 2003. Spatial variability of runoff and interrill erosion under different soils and land uses in a micro-catchment submitted to slash and burn. *The Lao Journal of Agriculture and Forestry*, 6:45-55.

de Rouw, A., Kadsachac, K, Gay, I., 2003. Four farming systems and comparative test for erosion, weeds and labour input in Luang Phrabang region. *New Thoughts*, 1:14-22, Perspectives on Lao development, first issue: food, fields and disasters, UNDP.

Moa, B., Valentin C., Marchand, P., Chaplot, V Sihavong, C., 2003. Flow discharge and sediment yield from a cultivated catchment in the northern Lao PDR. *The Lao Journal of Agriculture and Forestry*. 5:11-23.

Book chapters

Chaplot V., Giboire G., Marchand P., Valentin C, in press. Dynamic modeling for gully initiation and development under climate and land-use changes in northern

de Rouw, A.. "Good" and "bad" weeds in shifting cultivation, in press. Contribution to the Golden Book for prof dr. Ir. R. Oldeman. The Netherlands

Valentin, C., in press.. Overland flow, erosion and associated sediment and biogechemical transports. In: P. Kabat, M. Claussen, P. A. Dirmeyer, J. H.C. Gash, L. Bravo de Guenni, M. Meybeck, R. A. Pielke, Sr., C. J. Vörösmarty, R. W.A. Hutjes, S. Lütkemeier (Eds.); Vegetation, Water, Humans and the Climate. A New Perspective on an Interactive System. Springer verlag, Berlin, Global Change - The IGBP Series, 2003, 9 p.

Chaplot, V., A. Chanthavongsa, F. Agus, A. Boonsaner, R.O. Ilao, T.D. Toan, C. Valentin and N. Silvera. 2003. Evaluation of environmental factors and soil erosion in MSEC catchments. In: Maglinao, A.R, C. Valentin, and F. Penning de Vries (Eds.). From soil research to land and water management: Harmonizing people and nature. Proceedings of the *IWMI-ADB Project Annual Meeting and 7th Management of Soil Erosion Consortium (MSEC) Assembly*. pp. 129-138.

Dupin, B., K.B. Panthahvong, A. Chanthavongsa and C. Valentin. 2003. Tillage erosion on very steep slopes in northern Laos. In: Maglinao, A.R, C. Valentin, and F. Penning de Vries (Eds.). From soil research to land and water management: Harmonizing people and nature. Proceedings of the *IWMI-ADB Project Annual Meeting and 7th Management of Soil Erosion Consortium (MSEC) Assembly*. pp. 105-112.

Maglinao, A.R, C. Valentin, and F. Penning de Vries (Eds.). 2003. From soil research to land and water management: Harmonizing people and nature. Proceedings of the *IWMI-ADB Project Annual Meeting and 7th Management of Soil Erosion Consortium (MSEC) Assembly*. Thailand: IWMI. Southeast Asia Regional Office. 270 p.

Maglinao, A.R, C. Valentin and F. Penning de Vries. 2003. The Management of Soil Erosion Consortium (MSEC) Project: A case of integrated natural resource management research. In: Maglinao, A.R, C. Valentin, and F. Penning de Vries (Eds.). From soil research to land and water management: Harmonizing people and nature. Proceedings of the *IWMI-ADB Project Annual Meeting and 7th Management of Soil Erosion Consortium (MSEC) Assembly*. pp. 27-54

Others

MSEC, 2003. Catchment approach to managing soil erosion in Asia. Results and lessons learned. IWMI, ADB, IRD, Bangkok, 22 p., 6 tabl., 19 fig.

CD-ROM

Chaplot V, Phachomphon, K., Lestrelin, G., Silvera, N., Thiébaux J.P. 2003. Training workshop on: "Topography: from field survey to DEM generation". NAFRI, February 17-21, 2003 (LAOS-PDR).

Chaplot, V., Silvera, N., 2003. "On-the-job training" on : "Selection of optimal interpolation techniques at different scales" . NAFRI, 3-14 November 2003.

MSEC, 2003. Land and Water Management Research in the Uplands of South-East Asia, 30 September 2003, Vientiane, Lao PDR